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## THE FAUNA OF THE MIDDLE DEVONIAN FORMOSA REEF LIMESTONE OF SOUTHWESTERN ONTARIO


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ABSTRACT—The numerous reefs outcropping in the region around Formosa, Ontario, have been previously considered by various authors as equivalent to the Alpena limestone of Michigan, the Delaware limestone of Ohio, the Onondaga limestone of New York, and the Detroit River group of southwestern Ontario, southeastern Michigan, and northwestern Ohio. Outcrop and subsurface lithostratigraphic evidence indicates that the last correlation is correct. By means of detailed taxonomic study of the Formosa reef fauna an attempt was made to confirm this evidence paleontologically. One hundred twenty-eight species and subspecies have been identified and illustrated of which 31 species and 2 subspecies are new, 35 have been previously described, and 59 cannot be positively identified because of poor preservation. Sixty-six percent of the previously described species and subspecies are of Onondagan age (=Bois Blanc, Detroit River, and Columbus), 16% occur in both the Onondagan and Hamilton, and 16% were heretofore known only from the Hamilton. Of the Onondagan species only 4 are known to be restricted to the Detroit River group; all four occur in the Amherstburg dolomite which suggests a correlation of the Formosa reef limestone with the Amherstburg.


### INTRODUCTION

THE Formosa reef limestone consists of a localized three dimensional cluster of very pure, massive limestone reefs (bioherms) outcropping as irregular knobs in a roughly elliptical area in southern Bruce and northern Huron Counties, Ontario. The reefs are small, numerous, and occur sporadically through a stratigraphic interval of approximately 200 feet within the brown, bituminously laminated dolomite of the Middle Devonian Detroit River group (undifferentiated) (Fagerstrom, in press).

The regional stratigraphic relations of the Detroit River strata have been indicated by Ehlers, Stumm, & Kesling (1951, p. 24). In the northern portion of the southern peninsula of Michigan the Detroit River group is underlain by the Bois Blanc formation which contains the *Amphigenia* fauna characteristic of the lower Onondaga limestone of New York (Ehlers, 1945, p. 80, 106–107). In the quarries around Ingersoll, Ontario, Ehlers & Stumm (1951, p. 1881) reported the Columbus limestone with the upper Onondaga *Paraspirifer acuminatus* fauna overlying the Detroit River. The typical *Prosserella* fauna of the Detroit River group is not represented in the New York Onondagan. This led Ehlers, Stumm, & Kesling (1951, p. 24) to indicate an unconformity equivalent to the Detroit River between the *Amphigenia* and *Paraspirifer acuminatus* faunas. As yet the presence of such a depositional break in western New York has not been demonstrated; nonetheless the Bois

Blanc, Detroit River, and Columbus of southwestern Ontario are here considered to be of Onondagan age.

The problem of determining the proper sequence of the formations in the Detroit River group is difficult because the type localities are scattered, poorly exposed, and their faunas not properly described. The sequence given by Ehlers, Stumm, & Kesling (1951, p. 10) is Sylvania sandstone, Amherstburg dolomite, Lucas dolomite, and Anderdon limestone from bottom to top.

The repositories of the figured specimens are: UMMP—Museum of Paleontology, University of Michigan; USNM—U. S. National Museum, Washington, D. C.; GSC—Geological Survey of Canada, Ottawa.

ACKNOWLEDGMENTS

The author wishes to acknowledge with thanks the overall assistance and guidance of Dr. Erwin C. Stumm, who supervised the project, and Dr. G. M. Ehlers for his many helpful suggestions on the stratigraphic aspects and fossil collecting localities of the Formosa reefs.

In addition, the author is particularly indebted to Dr. D. J. McLaren, Geological Survey of Canada, and Dr. G. Arthur Cooper, U. S. National Museum, for the loan of many fossil specimens from the Formosa area in the collections of these institutions. Mr. Clinton F. Kilfoyle, New York State Museum, Albany, and Dr. Norman D. Newell, American Museum of Natural History, New York, loaned James Hall's type specimens of *Pentamerella pavilionensis, P. arata,* and *Productella navicella,* for which I am most thankful.

The generic determinations for the various groups have been checked by the following:

1. Stromatoporoids—Dr. J. J. Galloway, Indiana University.

2. Tetracorals, tabulate corals, and trilobites—Dr. Erwin C. Stumm, University of Michigan.

3. Bryozoa—Dr. M. K. Elias, University of Nebraska.

4. Brachiopods—Dr. G. Arthur Cooper, U. S. National Museum.

5. Pelecypods—Dr. A. L. LaRocque, Ohio State University.

6. Gastropods—Dr. R. M. Linsley, Colgate University.

7. Cephalopods—Dr. Walter C. Sweet, Ohio State University.

To all these workers the author is very grateful but he assumes sole responsibility for all taxonomic determinations made herein.

A grant from the Graduate Student Research Fund, University of Michigan, helped defray a large portion of the expense of visiting the Victoria Memorial Museum in Ottawa, Canada and the U. S. National Museum, Washington, D. C., as well as transportation to the Formosa area for fossil collection by the author during the summer of 1958. A portion of the cost of publication of the plates has been provided by a grant from the Faculty Research Council of the University of Nebraska.

## PREVIOUS INVESTIGATIONS

Studies of the fauna of the Detroit River group began in 1908 with the reading of a report of progress by Sherzer & Grabau at the Twentieth Annual Meeting of the Geological Society of America in Albuquerque, New Mexico. They discussed the stratigraphic relations of the formations, reported an unconformity between the group and the overlying Dundee limestone, and gave a synopsis of the fauna. The paper was published in the proceedings of the society (1909, p. 540–553).

Grabau & Sherzer (1910) completed a detailed stratigraphic and paleontologic report on the Detroit River group. In this book the fauna was discussed in detail, many new species were described and illustrated, and the age significance of the fauna was considered in relation to faunas of the better known areas of New York and the Appalachians. In both their 1909 and 1910 reports these authors concluded that the Detroit River group was of Late Silurian age.

The evidence for this conclusion was based primarily upon the fauna; in addition, the Detroit River—Dundee unconformity suited their stratigraphic arrangement and was considered to represent the entire Early Devonian (1910, p. 54). Having described the faunas of the various formations, Grabau (in Grabau & Sherzer, 1910, p. 217–234) then considered the age significance of each. He grouped the faunas of his Flat Rock, Anderdon, and Amherstburg as a lower unit of the Detroit River and noted (p. 217)

that " . . . if the fauna were considered by itself, it would probably be pronounced a Schoharie or an Onondaga fauna without a moment's hesitation, though there is a considerable Siluric element." With regard to the Lucas he concluded that " . . . it is throughout a Siluric fauna," (p. 221).

Thus, having noted this conflicting nature of the paleontologic evidence for the age of the Detroit River group, Grabau resolved the problem by disregarding the Devonian affinities of the Flat Rock-Anderdon-Amherstburg. He stated (p. 217), "The position of this fauna beneath 200 to 250 feet of the Lucas dolomite with a Siluric fauna, forces us to consider this as Siluric."

As early as 1916 Stauffer hinted (p. 73–74) that the youngest formation of the Detroit River group was the Anderdon limestone rather than the Lucas, as had been assumed by Grabau & Sherzer (1910, p. 27). However, it is important to note that it was not until nearly forty years later that Ehlers (1950) positively asserted that the Anderdon was the top of the Detroit River and it was not until 1951 that the evidence for this change was made known (Ehlers, Stumm, & Kesling, 1951, p. 9–11). Thus, from a purely stratigraphic viewpoint, there is considerable reason to doubt the Silurian affinities of the Lucas if it is overlain and underlain by formations bearing unquestionably Devonian faunas, i.e. the Amherstburg below and the Anderdon above.

Likewise it is significant to observe that Grabau (1910) did not completely overlook the possibility of a Devonian age for the Detroit River. On page 233 he discusses the faunal evidence for an early Devonian age for the group but then reasons that the time between the end of the deposition of the Detroit River strata and the beginning of Dundee deposition would not be sufficient to explain the magnitude of the unconformity between them. Again subsequent investigation by Ehlers, Stumm, & Kesling (1951, p. 9–11) indicates that the unconformity is not so important as visualized by Sherzer & Grabau (1909, Fig. 1, p. 541) and is in reality a rather short hiatus marked by minor erosion of the upper surface of the Anderdon limestone (Ehlers, Stumm, & Kesling, 1951, p. 25). In addition Grabau incorrectly correlated the Dundee with the Onondaga limestone of New York (1910, p. 234) rather than with the Marcellus formation (Ehlers, Stumm, & Kesling, 1951, p. 24). The upper Onondaga *Paraspirifer acuminatus* zone is not present in the area of Grabau's study and had he realized this, the problem of time for post-Detroit River—pre-Dundee erosion would have been less critical in his argument.

The next significant discussion of the fauna of the Detroit River group was by Stauffer (1915, p. 285–286). In his analysis of the relations of the fauna he at first (p. 271) followed the ideas of Grabau (1910) and considered it as Silurian. After citing additional stratigraphic evidence he concluded that, "There is no possibility that this fauna belongs in the Onondaga, to which it is most nearly related" (Stauffer, 1915, p. 285). Having made this assertion, Stauffer then retracted from so positive a stand and the reader is left confused by his final sentence (1915, p. 286), "The official practice of the Canadian Geological Survey is to treat the beds holding these faunas as part of the Devonian system." Were the views of Stauffer contrary to those of the survey or had he changed his mind and also considered the fauna as Devonian?

Again in his 1916 paper Stauffer is equally vague regarding his interpretation of the age of the Detroit River. However, he cites some faunal evidence (p. 73) which considerably weakens the force of Grabau's assertion (1910, p. 221) that the Lucas is unquestionably Silurian. In his summary Stauffer (p. 77) intimated that the Detroit River is of early Devonian age and might be in part equivalent to a portion of the Oriskany or Helderberg. This suggestion was offered perhaps as a convenient compromise to remove the Amherstburg fauna from the Silurian and yet not place it so high stratigraphically as the Onondaga where it faunally belonged.

However, the age of these strata was not settled until Williams (1919, p. 18–22) demonstrated conclusively that the fauna of the Detroit River was Devonian. His careful analysis of the relations of the fauna left no doubt as to its true Devonian aspect. In particular, he concluded his discussion of the Lucas fauna by regarding those supposed Silurian elements as holdovers rather than the primary age-determining constituents.

Since Grabau's comprehensive study, other contributions to the knowledge of the Detroit River fauna have been made by the following:

1. Stauffer (1918, p. 556–560) described four new species of brachiopods and two new species of gastropods from the Amherstburg dolomite. None of these species has as yet been collected from the Formosa reef limestone.

2. LaRocque (1950, p. 276–328) described seven species (two new) of pelecypods from the Detroit River strata in southeastern Michigan, none of which is known to occur in the Formosa reefs.

3. Ehlers, Stumm, & Kesling (1951, p. 34–35) illustrated the typical elements of the Amherstburg, Lucas, and Anderdon faunas but provided no accompanying descriptions.

4. Stumm (1953b) described and illustrated specimens comparable to *Proetus* (*Crassiproetus*) *crassimarginatus* (Hall) and a cephalon and pygidium of *Dechenella* (*Basidechenella*) *clara* (Hall) from the Amherstburg dolomite of southeastern Michigan. In addition he also figured the only type specimens known to have been described from the Formosa reef limestone. These were incomplete specimens of *P.* (*C.*) *crassimarginatus* (Hall).

5. Several faunal lists of the Detroit River group have been published, listing for the most part the typical fossils of the Onondaga limestone. These references include:

a. Stauffer, 1915, p. 274–284.
b. Caley, 1943, p. 38–43.
c. Best, 1953, p. 154–157, 162–163.
d. Stumm, Kellum, & Wright, 1956, p. 14, 16.

6. In addition, faunal lists of the Formosa reefs have been published by the following:

a. Stauffer, 1915, p. 141–148.
b. Caley, 1943, p. 47–49.
c. Roliff, Evans, & Caley, 1946, p. 15.
d. Best, 1953, p. 158–162.

## Register of Localities

The fossiliferous outcrops from which the specimens described in this report were collected are as follows (all localities in Bruce County, Ontario unless otherwise indicated):

*Locality*

4. Numerous outcrops in and around the village of Formosa, especially along the north-south paved road.

6. Highway road cut, 2.5 miles north of Formosa on Lot A, IIIS, Brant Twp., and Lot 72, Con. IS, Greenock Twp. This outcrop has been designated the type section of the Formosa reef limestone and has previously been described and illustrated by Stauffer (1915) under the name "Bruder's lime kiln." The present owner of the property adjacent to the road cut, William E. Merchant, upon questioning by the writer said that to his knowledge, the land had never been owned or leased by anyone named Bruder nor had anyone by that name ever operated a quarry or lime kiln at this locality. Stauffer's photograph (pl. XI) was taken on the east side of the outcrop looking west and the writer was able to locate certain landmarks (trees, rock exposures, etc.) which are still present and thus determine that this locality is the same as Stauffer's "Bruder's lime kiln."

Additional misunderstanding arises from the fact that Stumm (1953b, p. 28) listed the locality of the Formosa specimens illustrated as the "Marchand quarry." Further questioning of Mr. Merchant, by the writer, indicates that the land at this locality or at locality 12 (this report) was never owned or leased for quarrying purposes by anyone named Marchand and this name must have arisen by confusion with his name (Merchant).

12. A large abandoned quarry of the Ontario Hydro-Electric Co., Ltd., on the south side of Greenock Creek, Lots A and B, Con. IIIS, Brant Twp. According to William E. Merchant, the present owner of the land, the quarry has not been operated for about twenty years.

15. Numerous small knolls on the north side of a small unnamed tributary to the Teeswater River, 1.9 miles north of Belmore. Lots 8 and 9, Con. A, Carrick Twp.

18. Several small outcrops on both sides of the north branch of the Maitland River, 1.5 miles northeast of Wingham. Lot 20, Con. III, Turnberry Twp., Huron Co., Ont.

41. In the banks of the dredged portion of the Teeswater River about one-half mile west of Chepstow and one-fourth mile south of the bridge. Lot 8, Con. VI, Greenock Twp.

43. The Falls of the Teeswater River about three miles southeast of Teeswater. Lot 4, Con. III, Lots 3 and 4, Con. IV, Culross Twp.

45. Small outcrop along Ontario Highway No. 4, about one-half mile south of Salem. Lot 15, Con. XII, Culross Twp.

47. A high, vertical exposure along the road and several small wooded knolls to the north just east of the bridge where Formosa Creek crosses the road. Lots 3 and 4, Con. XI, Culross Twp.

53. A large knoll just north of the Teeswater

River and about 100–500 feet east of the road. Lot 5, Con. IV, Culross Twp.

62. A small abandoned quarry across the road from the community swimming pool in Teeswater. Lot 15, Con. VI, Culross Twp.

Unless otherwise indicated, all type specimens described in this report are catalogued in the Museum of Paleontology, University of Michigan, Ann Arbor.

## SYSTEMATIC DESCRIPTIONS

### Phylum, Class, Order UNCERTAIN
### Family RECEPTACULITIDAE
### Genus RECEPTACULITES Blainville

*Receptacules* Defrance, 1827, p. 5–7 (pending ICZN).
*Receptaculites* Blainville, 1830, p. 534.

*Type species.*—*Receptacules neptuni* Defrance.

#### RECEPTACULITES *sp.*
Pl. 3, fig. 28

*Remarks.*—A species of this genus is represented by a fragment too small for a species determination.

*Occurrence.*—Locality 12.

*Figured specimen.*—UMMP 36112.

### Genus EHLERSOSPONGIA, n. gen.

*Type species.*—*Ehlersospongia stellata*, n. sp.

*Description.*—Subpyriform to globose Receptaculitidae with expanded rhombic ossicles separated by an elevated wall forming a rough, reticulated external pavement. Individual ossicles depressed, with a small circular, shallow pit in the center from which vertical, raised partitions radiate outward.

*Remarks.*—The variation in the characteristics of this genus are unknown since it is described on the basis of a single specimen. It is distinguished by the elevated walls separating the ossicles, and the shallow pit and radiating ridges within each ossicle. The genus is named in honor of Dr. G. M. Ehlers, Museum of Paleontology, University of Michigan, who collected the only specimen known.

#### EHLERSOSPONGIA STELLATA, n. sp.
Pl. 3, figs. 21–23

*Description.*—Skeleton irregularly bent and twisted, subpyriform, with a somewhat rounded apex and an expanded base of attachment. Ossicles rhombic, smallest near apex, increasing in size toward the base and arranged in a spiralled pattern similar to that of a pine cone. Ossicles rather closely adjoined but separated by a prominent, elevated, thin wall giving a very rough external pavement. The floor of each depressed ossicle bears a small, circular, shallow pit from which radiate 5–15 vertical ridges resembling septa in the calyx of a colonial tetracoral. The ridges slope evenly downward from the junction with the walls between the ossicles to the edge of the pit at which point they remain somewhat elevated.

Dimensions of largest ossicles: maximum "diameter" of rhombs 8 mm., minimum "diameter" 6 mm., depth of floor below walls 1.5 mm.; maximum diameter of pits 1 mm.

*Remarks.*—The name of this species is derived from the Latin word "stella" and refers to the radiating ridges within the ossicles.

*Occurrence.*—Locality 12.

*Types.*—Holotype UMMP 36111, a very well preserved, nearly complete skeleton with three pieces of the incomplete external mold.

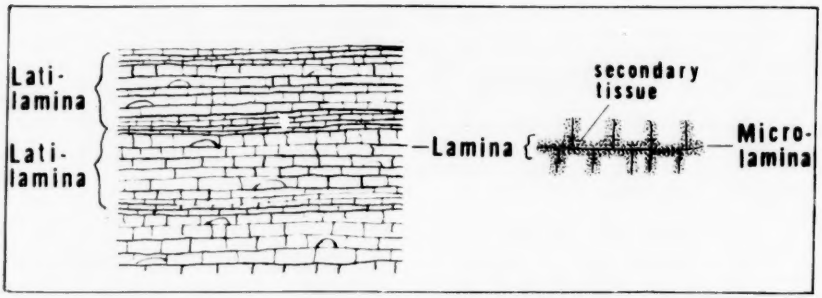
### Phylum COELENTERATA
### Class HYDROZOA
### Order STROMATOPOROIDEA

*Remarks.*—The two recent papers by Galloway (1957) and Galloway & St. Jean (1957) have facilitated the study of this heretofore poorly understood and controversial group; the glossary in the former paper is the basis for the morphological nomenclature used in the following systematic descriptions. Text-fig. 1 is included merely for a clearer understanding of the use of the terms latilamina, lamina, and microlamina.

### Family CLATHRODICTYIDAE
### Genus ANOSTYLOSTROMA Parks, 1936

*Type species.*—*A. hamiltonense* Parks.

*Remarks.*—The fauna of the Formosa reef limestone contains two genera of the family Clathrodictyidae; they are *Anostylostroma* and *Stictostroma*. In both these genera the laminae are porous and fibrous. However, in *Anostylostroma* the pores are minute and the laminae contain small vacuities (Galloway,




TEXT-FIG. 1—Diagram illustrating the use of the terms latilamina, lamina, and microlamina.

1957, p. 434), while in *Stictostroma* the laminae show "a thin, transversely porous, light median layer, with thinner, darker, transversely fibrous and porous layers on each side," (Galloway, 1957, p. 435). In the present study the distinction between these two genera has been made primarily on the basis of the relative size of the pores—those in *Anostylostroma* are very small and inconspicuous while the pores in *Stictostroma* are large and penetrate all three layers of the primary laminae as well as the secondary tissue in local areas. In many poorly preserved or strongly recrystallized specimens this distinction is difficult to ascertain and generic determinations are quite uncertain in such instances.

ANOSTYLOSTROMA ARVENSE (Parks)
Pl. 2, figs. 1–3

*Clathrodictyon arvense* Parks, 1936, p. 23.
*Anostylostroma arvense* Galloway & St. Jean, 1957, p. 110–111.

*Remarks.*—Galloway & St. Jean (1957, p. 110) have described the laminae of this species as "consisting of one layer, which is light in color and transversely fibrous." There is no mention of any secondary thickening nor do the plates show any such tissue (Galloway & St. Jean, 1957, pl. 4, fig. 1). In the fauna of the Formosa reef limestone there are two distinct forms of the genus *Anostylostroma*. One form is without secondary tissue, a typical *A. arvense;* the other has considerable secondary tissue and is herein described as a new subspecies of *A. arvense*. In neither of these forms is there notable expansion of the pillars upward in any manner described by Galloway (1957, p. 434) as typical of the genus *Anostylostroma* and so in the Formosa area this feature of the pillars is of no taxonomic value in distinguishing between *Anostylostroma* and *Stictostroma*.

*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36196–36198 and 36206.

ANOSTYLOSTROMA ARVENSE DENSILAMINATUM, n. subsp.
Pl. 2, figs. 4–6

*Description.*—Coenosteum flat, massive, up to 40 mm. thick and 130 mm. long. Surface undulating with variously shaped, irregularly spaced, low to conical mammalons 3–9 mm. in diameter, 0.5–2 mm. high, and spaced 5–15 mm. center to center. Astrorhizae absent.

Vertical section: Laminae, pillars, and dissepiments are clearly defined structures consisting of one thin, dark, microlamina about 0.03 mm. thick with considerable secondary tissue on the surfaces to give a total thickness of as much as 0.12 mm; both the microlamina and the secondary tissue are fibrous and porous. Laminae widely spaced, 4–6 in 2 mm., and not grouped into latilaminae. Pillars not superposed to form continuous columns, Y-shaped, or enlarged upward; most pillars are complete and spaced 2–3 in 1 mm. Galleries rectangular, 0.3–1 mm. in longest dimension, not superposed; many galleries are partially or almost completely filled with secondary tissue. Dissepiments nearly as numerous as pillars, arched upward; commonly occurring as a contin-

uous series of overlapping plates between two laminae. Mammalons clearly defined areas of dense accumulation of secondary tissue completely filling the galleries; laminae, pillars, and dissepiments incomplete, irregular, and partially destroyed or resorbed.

Tangential section: About 65% of the area consisting of dense, secondary tissue in the galleries. Pillars mostly round, 0.1–0.15 mm. in diameter, commonly joined in angular, vermicular chains by curved dissepiments. Mammalons indicated by dense secondary tissue completely filling the galleries, thickened pillars and incomplete dissepiments. Astrorhizae absent.

*Remarks.*—The specimens of this subspecies from the Formosa reef limestone resemble *A. arvense* (Parks) in all respects except for the considerable amount of secondary thickening of the laminae, pillars, and dissepiments. This secondary accumulation of calcium carbonate may have no taxonomic significance and may merely be a response by the living stromatoporoid colony to a reef environment rich in calcium carbonate. However, until such a response has been demonstrated, the specimens from the Formosa area are herein treated as a subspecies.

*Occurrence.*—Locality 6.

*Types.*—Holotype UMMP 36192 and paratypes UMMP 36193–36195.

Genus STICTOSTROMA Parks, 1936, p. 78

*Type species.*—*S. mamilliferum* Galloway.

STICTOSTROMA MCCANNELLI, n. sp.
Pl. 2, figs. 7–9

*Description.*—Coenosteum flat or slightly convex; surface papillate but without conspicuous astrorhizae. Mammalons 4–6 mm. in diameter, 0.5–2 mm. high, and spaced 6–8 mm. center to center. Latilaminae prominent to obscure and 1–3 mm. thick.

Vertical section: Laminae 11–13 in 2 mm., rather uniformly about 0.1 mm. thick; primary laminae transversely fibrous and porous and consisting of three layers—a thick median layer of dense, dark tissue with a thinner, darker layer of tissue on both the upper and lower surfaces. In most specimens the primary laminae locally thickened by secondary tissue which may partially or completely fill the adjacent galleries. Galleries round, oval, or elongate parallel to laminae, greatest diameter from 0.1–0.4 mm.; galleries not superposed to form pseudozooidal tubes. Pillars 0.1–0.2 mm. thick, spindle-shaped, 4–6 in 1 mm.; not transversely fibrous or porous nor superposed into long columns. Since the vertical "diameter" of the galleries is commonly somewhat greater than the height of the pillars, the laminae are not straight but undulate around the galleries and down into the pillars. Mammalons marked by a slight increase in secondary tissue in the galleries and thickening of the pillars. Dissepiments thin, highly arched, rare.

Tangential section: Laminae appear as wandering, dense, transversely fibrous and porous layers between the open areas of the galleries. Pillars round, oval, or elongate, 0.1–0.2 mm. in diameter. Astrorhizae short, 0.1–0.15 mm. thick, and generally with a few thin tabulae. Dissepiments thin, without secondary thickening, arched between pillars and appearing to be more abundant than observed in vertical section.

*Remarks.*—This species is characterized by having conspicuous three-layered, porous primary laminae with considerable secondary thickening and rather prominent, regular mammalons with short, tabulate astrorhizae. *A. mccannelli* is named for Mr. E.S. McCannel of Walkerton, Ontario to whom the author is greatly indebted for aid in his field studies in the Formosa area.

*Occurrence.*—Localities 6, 53.

*Types.*—Holotype UMMP 36199 and paratypes UMMP 36200–36205.

STICTOSTROMA LONGITUBIFERUM, n. sp.
Pl. 1, figs. 8,11

*Description.*—Coenosteum a gently undulating, massive, flat fragment 75 mm. long and 5–10 mm. thick. Surface conspicuously papillate; mammalons about 0.5 mm. high, 5–7 mm. in diameter, and irregularly arranged 5–15 mm. center to center. A large and prominent astrorhiza occupies each mammalon; astrorhizae with a maximum diameter of 12 mm., branches radiating with large open canals which sometimes divide dendritically or intermingle with those of adjacent astrorhizae. Latilaminae 1–1.5 mm. thick, not conspicuous but speci-

men tends to weather and break between them.

Vertical section: Primary laminae transversely porous and fibrous, 8–10 in 2 mm., and 0.05–0.1 mm. thick. Most laminae considerably thickened by secondary tissue on the lower surface making a total laminar thickness of as much as 0.15 mm. Pillars 0.08–0.2 mm. thick, often incomplete, irregular in position and spaced 3–5 in 1 mm., not transversely porous and fibrous or superposed into continuous columns, and consisting for the most part of irregular accumulations of secondary tissue extending downward from the laminae. Galleries extremely variable in position and size, 0.1–0.5 mm. in greatest diameter, and not superposed into pseudozooidal tubes. Mammalons not definite structures marked by sharply upbent laminae or greater tissue accumulation. Dissepiments numerous, both complete and incomplete, consisting of thin arching layers of non-porous and non-fibrous tissue without secondary deposits.

Tangential section: Skeletal tissue represents about 60% of the section; it includes irregularly wandering laminae, round, oval, or elongate vermicular pillars 0.1–0.3 mm. in greatest dimension, and thin, arching or straight dissepiments connecting some of the pillars. The astrorhizal tubes are prominent, long, and up to 0.3 mm. wide; they radiate irregularly from the mammalon centers, are generally non-tabulate, and without secondary tissue.

*Remarks.*—*Anostylostroma longitubiferum* is characterized by large, prominent astrorhizae, low indefinite mammalons, and laminae with considerable secondary tissue mostly on the lower surface. It lacks the conspicuously three-layered laminae of *Strictostroma mccannelli*, n. sp.

*Occurrence.*—Locality 6.

*Types.*—Holotype UMMP 36207 and paratypes UMMP 36208, 36209.

Family STROMATOPORIDAE
Genus STROMATOPORA Goldfuss, 1826

*Type species.*—*S. concentrica* Goldfuss.

STROMATOPORA PROXILAMINATA, n. sp.
Pl. 1, figs. 4–6

*Description.*—Coenosteum large and massive occurring as flat expansions up to one foot or more in diameter; papillate. Mammalons 8–10 mm. in diameter, 2–3 mm. high, and 10–12 mm. center to center. Astrorhizae inconspicuous on weathered surface, short, small. Latilaminae strongly marked, 1–1.3 mm. thick; coenosteum splits and weathers between the latilaminae.

Vertical section: Microlaminae undulose, parallel, 20–22 in 2 mm., 0.015–0.04 mm. thick, markedly grouped into latilaminae composed of 3–5 laminae, and consisting of thin layers of dark, dense, evenly maculate tissue somewhat thickened by lighter, less dense secondary maculate tissue. Galleries abundant, irregularly spaced but most frequent in the upper half of the interlaminar spaces, round, oval, and rectangular averaging 0.2 mm. in diameter but not uncommonly elongated parallel to the laminae to a diameter of as much as 0.7 mm. Occasional superposed galleries tend to become elongated into short, narrow, tabulate pseudozooidal tubes occupying the space between 3 or 4 laminae. Pillars not definite structures, thick, irregular, massive, 0.1–0.2 mm. in diameter, 2–3 in 1 mm., not superposed in long continuous columns and becoming thicker and more conspicuous in the mammalons. Dissepiments absent.

Tangential section: About 70% of the area consists of fine, rather evenly maculate tissue of the pillars and laminae in which are located irregular, coalescing, vermicular openings of the galleries, and non-tabulate pseudozooidal tubes and astrorhizae. Mammalons without axial tubes.

*Remarks.*—This species is characterized by the very close spacing of the laminae, their marked grouping into latilaminae, and relatively fewer pseudozooidal tubes than is common for the genus *Stromatopora*. The laminae are more closely spaced and not separated by light colored microlaminae as in *S. mononensis* Galloway and St. Jean; they are more closely spaced and not as greatly thickened by secondary maculate tissue as *S. densilaminata*, n. sp. *S. proxilaminata* is the most abundant species of the stromatoporoids in the Formosa reef limestone.

*Occurence.*—Localities 6, 12

*Types.*—Holotype UMMP 36177 and paratypes UMMP 36178–36186.

STROMATOPORA DENSILAMINATA, n. sp.
Pl. 1, figs. 7,10

*Description.*—Coenosteum of holotype consists of an irregular, papillate fragment 7 mm. thick and about 40 mm. in diameter. Surface with weathered mammalons 3–4 mm. in diameter, 1 mm. high, and 4–6 mm. from center to center. Astrorhizae apparent only on unweathered lower surface and laminae only on freshly broken sections.

Vertical section: Microlaminae undulose, parallel, 9–11 in 2 mm., 0.015–0.03 mm. thick, not markedly grouped into latilaminae and consisting of thin, dense sheets of dark, maculate tissue with greatly thickened upper surfaces of less dense, light, secondary maculate tissue which grades imperceptibly into thick, irregular pillars. Galleries irregularly concentrated in the upper half of the interlaminar spaces, generally round or slightly oval but occasionally elongate parallel to the laminae and ranging from 0.15–0.2 mm. in diameter. Pseudozooidal tubes rather abundant, mostly tabulate and consisting of from 2–5 superposed galleries. Pillars not definite structures, 4–6 in 1 mm., and not generally superposed to form continuous columns. In the mammalons the amount of tissue in the pillars and thickened laminae increases, the pseudozooidal tubes are wider and longer, and the galleries more elongate than round. Dissepiments absent.

Tangential section: The galleries appear as small circular openings 0.05–0.1 mm. in diameter or vermicular passages set in the evenly maculate tissue of the laminae and pillars which occupies about 80% of the area. Astrorhizae short, mostly non-tabulate, and radiating from mammalon centers having no axial tubes.

*Remarks.*—*S. densilaminata* is characterized by thick secondary accumulations of light, maculate tissue on the upper surfaces of the laminae which grades into the massive, similar tissue of the pillars. The pseudozooidal tubes are wider and more abundant than in either *S. mononensis* Galloway and St. Jean or *S. proxilaminata*, n. sp.

*Occurrence.*—Localities 6, 12.

*Types.*—Holotype UMMP 36175 and paratype UMMP 36176.

Genus SYRINGOSTROMA Nicholson, 1875

*Type species.*—*S. densum* Nicholson.

SYRINGOSTROMA PROBICRENULATUM, n. sp.
Pl. 1, figs. 1–3

*Description.*—Coenosteum papillate, massive, flat, 2.5 cm. thick and 11 cm. long. Surface covered by sharply conical mammalons 1–2 mm. high, 3–5 mm. in diameter, and spaced 7–10 mm. center to center. Astrorhizae not generally apparent on the weathered surface. Latilaminae appear as light gray undulating bands 0.8–1 mm. thick on unweathered vertical fractures.

Vertical section: Laminae nearly parallel, undulating evenly into the mammalons and sharply bent upward into the larger pillars, 16–20 in 2 mm. Microlaminae about 0.02 mm. thick, consisting of a thin layer of dense, dark, maculate tissue with considerable secondary thickening on both the upper and lower surfaces. Galleries round, oval, or elongate parallel to the laminae, from 0.1–0.5 mm. in diameter generally occupying the entire interlaminar space. There is a slight tendency toward superposition of 2 or 3 galleries to form tabulate pseudozooidal tubes. Pillars of two types and sizes. Smaller pillers not definite structures, generally confined between two laminae and not forming continuous columns; they are 0.1–0.2 mm. in diameter, spindle-shaped, and spaced 3–4 in 1 mm. The larger pillars are clearly defined, thickened areas of rather dense, dark, non-laminar, maculate tissue, 1–2 mm. long, of variable diameter from 0.2–0.4 mm., and sporadically spaced between the mammalons. Astrorhizal canals appear as round or oval, non-tabulate open areas 0.1–0.2 mm. in diameter. In the larger astrorhizal canals the laminae either end abruptly at the borders or bend around them. Mammalons are areas of thickened, more dense pillars, larger galleries, and more numerous astrorhizal canals through which the laminae undulate, become less distinct, or even lose their identity. Dissepiments absent.

Tangential section: About 80% of the area consists of dense, dark, maculate tissue of the pillars and thickened laminae. The galleries appear as irregularly oval or elongate, anastomosing, vermicular open areas. Astrorhizae are mostly non-tabulate, rather straight, clearly defined tubes radiating from the mammalons, 0.2 mm. in diameter and up to 2 mm. long.

*Remarks.*—This species closely resembles *S. bicrenulatum* Galloway & St. Jean but differs in the following respects: the larger pillars are more irregular in shape, less numerous, and non-laminate; the astrorhizal canals are less numerous and slightly larger.

*Occurrence.*—Localities 6, 12.

*Types.*—Holotype UMMP 36187, paratypes UMMP 36188 and 36189.

SYRINGOSTROMA SHERZERI (Grabau)
Pl. 1, figs. 9,12

*Stylodictyon sherzeri* Grabau, 1910, p. 92–94, pl. VI, figs. 4,5.

*Revised description.*—Coenosteum massive; upper surface slightly convex, without mammalons or astrorhizae, and covered with round, depressed pits 1–1.5 mm. in diameter, 0.5 mm. deep, and spaced 1.5–3 mm. center to center. Latilaminae prominent, light gray, 1.5–2 mm. thick, and consisting of 3–5 microlaminae.

Vertical section: Microlaminae 12–14 in 2 mm., 0.02–0.05 mm. thick, consisting of a thin layer of dense, dark maculate tissue, generally without much secondary thickening. Galleries large, abundant, irregularly scattered but generally confined between adjacent laminae, round, oval, and elongate both parallel and perpendicular to the laminae, and from 0.1–0.7 mm. in greatest dimension. Pseudozooidal tubes abundant, up to 1 mm. long and 0.15 mm. wide, generally not straight, and both with and without tabulae. Pillars of two types and sizes. The smaller pillars are less prominent than the galleries and pseudozooidal tubes, spindle-shaped, 0.1–0.3 mm. in diameter, 3–4 in 1 mm., and not forming continuous columns. The larger pillars are clearly defined by the sharp upbending of the laminae and the accumulation of more dense, dark, coarsely maculate tissue which nearly obscures the laminae as they pass through; these pillars are 0.2–0.3 mm. wide and those intersecting the surface of the coenosteum lie in the centers of the circular, depressed pits. Dissepiments absent.

Tangential section: The dominant feature of the tangential section is the numerous, circular areas of coarse, maculate tissue of the large pillars. These areas are 1–2 mm. in diameter, irregular in arrangement, and spaced 1.5–3 mm. center to center; each pillar area has one circlet of regularly spaced, round, vertical tubes around the periphery within the ring formed by the lamina nearest the pillar and one or two circlets of less distinct vertical tubes outside this ring. The number of these tubes to a pillar ranges from 6–13 depending to some extent on the diameter of the pillar; their diameter is from 0.15–0.20 mm. The remainder of the area consists of large, irregular open spaces of the galleries and irregular, coarsely maculate tissue of the smaller pillars. Astrorhizal canals absent.

*Remarks.*—The presence of this species, originally described from the Amherstburg dolomite of the Detroit River group and so far as is now known restricted to this formation, adds considerable support to the Detroit River age of the Formosa reef limestone.

*Occurrence.*—Localities 6, 45.

*Types.*—Hypotypes UMMP 36190 and 36191.

SYRINGOSTROMA CYLINDRICUM, n. sp.
Pl. 2, figs. 10–14

*Description.*—Coenosteum nearly cylindrical, about 18 mm. in diameter; surface poorly known but apparently without mammalons or astrorhizae; probably papillate. Latilaminae not prominent; 0.5–1.5 mm. thick.

In the transverse section normal to the axis of the coenosteum there is a rather large central area about 6 mm. in diameter, consisting of an irregular meshwork of non-laminar maculate tissue with short, vermicular, open passages. The laminae appear as slightly elliptical, closed loops around the central axis; 8–10 in 2 mm. Microlaminae consist of very thin (about 0.02 mm.) layers of dark, dense maculate tissue with a great deal of secondary maculate tissue on both the upper and lower surfaces. The galleries are most abundant in the lower half of the interlaminar spaces; they are generally elongate either parallel to or normal to the laminae but not superposed to form pseudozooidal tubes. They range from 0.1–0.6 mm. in greatest dimension. Pillars of two types and sizes; the smaller ones are abundant, indefinite accumulations of secondary tissue, 0.05–0.3 mm. in diameter, 3–5 in 1 mm.,

and tending to be superposed between 3 or 4 laminae. The larger pillars are typical of the genus *Syringostroma;* they are marked by a sharp upbending of the laminae into columns of dense maculate tissue where the laminae tend to fuse or be resorbed and in some cases lose their identity. The larger pillars are comparatively short, about 0.3 mm. in diameter, and spaced irregularly from 1–1.5 mm. apart. Mammalons and dissepiments absent.

In both specimens of this species collected from the Formosa reef limestone there is an unusually great accumulation of secondary tissue in the outer 1 to 1.5 mm. of the coenosteum. As seen in tangential section the laminae have been almost completely destroyed and the galleries are very small and not joined in vermicular chains. Astrorhizae are rather abundant, large, and nontabulate.

In the section cut longitudinally parallel to the axis of the coenosteum the central meshwork of tissue appears as elongated strands parallel to the axis and radiating outward toward the surficial laminated area. The laminae, galleries, and smaller pillars are the same as in the transverse section but the larger pillars are more abundant, prominent, and somewhat longer and wider.

*Remarks.*—*Syringostroma cylindricum* is easily distinguished from all other described species in this genus by the external cylindrical shape of the coenosteum.

*Occurrence.*—Localities 6, 47.

*Types.*—Holotype UMMP 36210 and unfigured paratype UMMP 36211.

SYRINGOSTROMA AMBIGUUM, n. sp.
Pl. 1, figs. 13–15

*Description.*—Coenosteum a slightly convex, massive fragment 15 mm. thick and 50 mm. long. Surface poorly preserved, irregularly undulating, without mammalons, probably without papillae, but with long, narrow, anastomosing astrorhizae. On the vertical fracture latilaminae prominent and 1–1.5 mm. thick. Large pillars prominent, light gray, 0.3–0.5 mm. thick and 1–3 mm. apart. Astrorhizal canals appear as conspicuous, clear, circular areas.

Vertical section: Microlaminae extremely thin and numerous, irregularly spaced, 30–40 in 2 mm., but with abundant accumulation of secondary maculate tissue which has filled most of the galleries. The galleries which have retained their identity are round, oval, and elongate, 0.1–0.4 mm. in greatest dimension, and are clustered in local areas of lesser amounts of secondary tissue where they are separated by indefinite small pillars. The larger sized pillars, so typical of the genus *Syringostroma,* are rather prominent and abundantly represented by long columns of dense, dark, maculate tissue delimited by sharply upbent laminae which lose their identity within the pillars. Astrorhizal canals are a dominant feature of the vertical section; they appear as large, irregularly spaced, round spaces 0.3–0.5 mm. in diameter in the tissue and occur both with and without tabulae. Pseudozooidal tubes, mammalons, and dissepiments absent.

Tangential section: About 80–85% of the area consists of dense, dark, maculate tissue rather evenly distributed over most of the section. The open spaces of the galleries are of minor importance. The smaller pillars are indistinguishable from the laminae and are very irregularly distributed. The larger pillars are not prominent but in most instances are partially encircled by a discontinuous, irregular gallery. The astrorhizal canals, which are the dominant feature of the tangential section, are long, wide, vermicular, bifurcating open areas, generally without tabulae.

*Remarks.*—*Syringostroma ambiguum,* n. sp., and *S. radicosum* Galloway & St. Jean bear considerable resemblance in that both have large astrorhizal canals; however, *S. ambiguum* has no mammalons and the microlaminae are more numerous and less persistent through the larger pillars than in *S. radicosum.*

*Occurrence.*—Locality 6.

*Type.*—Holotype UMMP 36212.

Class ANTHOZOA
Subclass TETRACORALLIA
Family ZAPHRENTIDAE
Genus HETEROPHRENTIS Billings

*Heterophrentis* Billings, 1874, p. 235.
*Triplophyllum* Simpson, 1900, p. 209.

*Type species.*—*Zaphrentis spatiosa* Billings.

HETEROPHRENTIS ? sp.
Pl. 4, fig. 7

*Remarks.*—Several very poorly preserved specimens are questionably referred to this genus. They are distinguished by short, alternating major and minor septa; no tabulae are preserved.
*Occurrence.*—Localities 4, 6, 47.
*Figured specimen.*—UMMP 36130.

Genus ZAPHRENTIS Rafinesqe & Clifford

*Zaphrentis* Rafinesque & Clifford, 1820, p. 234; Milne-Edwards & Haime, 1850.
*Helenterophyllum* Grabau, 1910, p. 95–98.
*Heliophrentis* Grabau, 1910, p. 98.

*Type species.*—*Z. phrygia* Rafinesque & Clifford.

ZAPHRENTIS sp.
Pl. 4, fig. 3

*Remarks.*—This genus is represented by a single, rather poorly preserved calyx with denticulate major and minor septa.
*Occurrence.*—Locality 15.
*Figured specimen.*—UMMP 36128.

Genus SIPHONOPHRENTIS O'Connel, 1914

*Type species.*—*Caryophyllia gigantea* Lesueur.

SIPHONOPHRENTIS GIGANTEA Lesueur
Pl. 4, fig. 5

*Caryophyllia gigantea* Lesueur, 1821, p. 296.
*Siphonophrentis gigantea* O'Connell, 1914, p. 187, 191.

*Remarks.*—Several specimens of this species, all incomplete, have been collected. They range in diameter from less than 3 cm. to slightly over 5 cm. and are up to 15 cm. long.
*Occurrence.*—Localities 6, 12.
*Type.*—Hypotype UMMP 36146.

SIPHONOPHRENTIS sp.
Pl. 4, fig. 6

*Remarks.*—A single immature portion of a corallite with all the diagnostic features of the genus *Siphonophrentis* was collected. The tabulae appear to be too strongly arched for typical *S. gigantea*.
*Occurrence.*—Locality 12.
*Figured specimen.*—UMMP 36147.

Family BETHANYPHYLLIDAE
Subfamily BLOTHROPHYLLINAE

Genus BLOTHROPHYLLUM Billings, 1859

*Type species.*—*B. decorticatum* Billings.

BLOTHROPHYLLUM sp.
Pl. 4, fig. 4

*Remarks.*—This genus is represented by a single, very poorly preserved specimen from which it is impossible to determine the species.
*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36113.

Family ACANTHOPHYLLIDAE
Genus HELIOPHYLLUM Hall, 1846

*Type species.*—*Strombodes helianthoides* Hall.

HELIOPHYLLUM sp. cf. H. INCRASSATUM Hall
Pl. 4, figs. 10,11

*Heliophyllum incrassatum* Hall, 1882, p. 46.

*Remarks.*—Two rather poorly preserved specimens compare favorably with this species in possessing slightly dilated septa and a rather wide tabularium, but with fewer tabellae than in typical *H. incrassatum*.
*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36144.

HELIOPHYLLUM sp. cf. H. VERTICALE Hall
Pl. 4, figs. 1,2

*Heliophyllum verticale* Hall, 1882, p. 47.

*Remarks.*—Several specimens from the Formosa reefs may be referred to this species; however, the exterior annulations are not apparent from the state of preservation.
*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36143.

HELIOPHYLLUM sp.
Pl. 4, figs. 8,9

*Remarks.*—Two very poorly preserved specimens of the genus *Heliophyllum* have been collected having thin, non-dilated septa which do not quite meet at the axis of the calyx and a wide non-tabellate dissepimentarium. This may be a new species but the specimens are too incomplete to be certain.
*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36145.

Family COLUMNARIIDAE
Subfamily COLUMNARIINAE
Genus SYNAPTOPHYLLUM Simpson, 1900

*Synaptophyllum* Simpson, 1900, p. 212; McLaren, 1959, p. 16–18; *non* Stumm, 1949, p. 37.

*Type species.*—*Diphyphyllum arundinaceum* Billings.

SYNAPTOPHYLLUM GRABAUI, n. sp.
Pl. 3, figs. 11–14

*Diplophyllum integumentum* Grabau, 1910, *partim*, p. 106–108, pl. 10, fig. 1, pl. 15, figs. 9,10, *non* pl. 16, figs. 15,17, *non Diphyphyllum integumentum* Barrett, 1878, p. 123.

*Description.*—In transverse section the septa are noncarinate, all of about the same length, extending nearly to the center of the corallite where they are rather thin and incomplete. Toward the periphery the septa become dilated and grade into a 1 mm. thick stereozone. The number of septa range from about 20 to 28, averaging about 25. Diameter of mature corallites 7–12 mm., averaging about 9 mm.

In longitudinal section the tabulae are generally complete, tending to be somewhat evenly depressed toward the center of the corallite, and spaced about 7 in 10 mm. Dissepiments absent.

Exterior features unknown from specimens in the Formosa reef limestone; they are however, presumed to agree with Grabau's (1910, p. 106–108) detailed description of the numerous specimens from the Anderdon and Amherstburg limestones along the Detroit River.

*Remarks.*—The discovery of two incomplete specimens of this species known only from the Detroit River group helps substantiate the Detroit River age of the Formosa reef limestone. *S. grabaui* differs from *Diphyphyllum integumentum* Barrett in not having dissepiments, fasciculate coralla, or minor septa, and having only about half as many major septa.

*Occurrence.*—Formosa reef limestone, locality 12, and the Anderdon and Amherstburg limestones along the Detroit River.

*Types.*—Holotype UMMP 13083, a complete corallite from the Amherstburg dolomite, paratypes UMMP 13064, a large slab with several incomplete corallites also from the Amherstburg dolomite, and UMMP 36116 and 36117, incomplete corallites from the Formosa reef limestone.

Genus PLACOPHYLLUM Simpson, 1900

*Type species.*—*P. tabulatum* Simpson.

PLACOPHYLLUM ? sp.
Pl. 4, fig. 15

*Remarks.*—A great many incomplete specimens with short septa or septal ridges, flat, complete tabulae, and no dissepiments have been collected. Since the nature of the septa in the genus *Placophyllum* is unknown, these specimens can only be questionably referred to it.

*Occurrence.*—Localities 6, 12.
*Figured specimen.*—UMMP 36125.

Genus DEPASOPHYLLUM Grabau, 1936

*Type species.*—*D. adnetum* Grabau.

DEPASOPHYLLUM sp. cf. D. ADNETUM
Grabau Pl. 4, fig. 14

*Depasophyllum adnetum* Grabau, 1936, p. 44; Ehlers & Stumm, 1949, p. 30–31.

*Remarks.*—A single poorly preserved, half corallite which compares favorably with *D. adnetum* was collected. The septa are amplexoid, extending no more than one-fourth the distance to the corallite axis and without intervening dissepiments.

*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36124.

DEPASOPHYLLUM ? sp.
Pl. 4, figs. 12,13

*Remarks.*—Several specimens with somewhat longer septa than *D. adnetum* and with a few dissepiments in the marginarium may be questionably referred to *Depasophyllum* because they possess "pill-box" tabulae, a diagnostic feature of the genus.

*Occurrence.*—Localities 6, 12.
*Figured specimen.*—UMMP 36123.

Family DISPHYLLIDAE
Subfamily DISPHYLLINAE
Genus DISPHYLLUM de Fromentel, 1861

*Type species.*—*Cyathophyllum caespitosum* Goldfuss.

DISPHYLLUM sp. A
Pl. 3, figs. 1–3

*Remarks.*—Several specimens of this species have been collected. They have a nar-

row, incomplete dissepimentarium which makes a species determination very uncertain. In addition the longitudinal section illustrated in Pl. 4, Fig. 1 looks as though the septa are carinate, in which case the specimen would be referred to the genus *Cylindrophyllum*. Since there is no indication of carinae on the septa in the transverse section, the specimen is here considered in the genus *Disphyllum*.

*Occurrence.*—Localities 6, 12.

*Figured specimen.*—UMMP 36118.

DISPHYLLUM sp. B
Pl. 3, figs. 9,10

*Remarks.*—A single, very poorly preserved specimen, considerably larger and with a wider dissepimentarium than *D. sp. A* above was collected. The preservation is too poor for species determination.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36119.

Genus CYLINDROPHYLLUM Simpson, 1900

*Cylindrophyllum* Simpson, 1900, p. 217.
*Cylindrohelium* Grabau, 1910, p. 102.
*Spinophyllum* Wedekind, 1922, p. 5.

*Type species.*—*Cylindrophyllum elongatum* Simpson.

CYLINDROPHYLLUM sp. cf. C. ELONGATUM Simpson
Pl. 3, figs. 7,8

*Remarks.*—This species is represented by one very incomplete corallite. Simpson in the original description (1900, p. 218) notes that the minor septa are very short; however, in the Formosa reef limestone specimen all the septa are apparently about the same length.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36142.

CYLINDROPHYLLUM sp. cf. C. PROPINQUUM Stewart
Pl. 3, figs. 4–6

*Cylindrophyllum propinquum* Stewart, 1938, p. 45.

*Remarks.*—Two specimens rather strongly resemble this species but have about 10 fewer septa and the carinae are not as abundant. Nothing is known of the nature of the corallum since both specimens are isolated corallites.

*Occurrence.*—Locality 6.

*Figured specimens.*—UMMP 36114 and 36115.

Subfamily PACHYPHYLLINAE
Genus ACINOPHYLLUM McLaren 1959

*Type species.*—*Eridophyllum simcoense* Billings.

ACINOPHYLLUM MCLARENI, n. sp.
Pl. 3, figs. 18–20

*Description.*—Coralla large, phaceloid, composed of numerous, closely spaced, long, nearly straight, cylindrical corallites with occasional lateral epithecal projections. Calices unknown. Corallites about 7 mm. in diameter; septa of two orders, inconspicuously carinate, and somewhat wavy and dilated toward the thin epitheca. Major septa 28–30, long, axially attenuate, nearly reaching the corallite axis. Minor septa of about the same thickness as the peripheral portion of the major septa and about half as long. Dissepiments horseshoe shaped, arranged in one (occasionally two) vertical rows at or near the periphery. If a second row of dissepiments is present it is rather discontinuous and the dissepiments are smaller and inclined toward the axis more than those in the major peripheral row. Tabularium wide; tabulae well developed, variably spaced from 5 to 7 in 5 mm., complete, horizontal axially, becoming rather sharply deflected downward peripherally but not resting on the tabula below.

*Remarks.*—This species most nearly resembles *Acinophyllum baculoideum* (Simpson) but differs significantly in having about one-third more major septa in the same size corallites. Isolated, short, incomplete, stem-like corallites of *A. mclareni* are very abundant in the Formosa reefs but specimens having more than one or two corallites are rare.

*Occurrence.*—Localities 6, 12, 43, 53.

*Types.*—Holotype UMMP 36120, a large incomplete corallum, and paratype UMMP 36121.

Subfamily ERIDOPHYLLINAE
Genus ERIDOPHYLLUM Milne-Edwards & Haime, 1850

*Type species.*—*E. seriale* Milne-Edwards & Haime.

ERIDOPHYLLUM SERIALE Milne-Edwards & Haime
Pl. 3, figs. 15,16

*Eridophyllum seriale* Milne-Edwards & Haime, 1850, p. lxxi; Stewart, 1938, p. 41–42.

*Remarks.*—One corallite of this species has been collected from the Formosa reef limestone.

*Occurrence.*—Locality 6.
*Type.*—Hypotype UMMP 36122.

Family CYSTIPHYLLOIDIDAE
Subfamily CYSTIPHYLLOIDINAE
Genus CYSTIPHYLLOIDES Chapman, 1893

*Type species.*—CYSTIPHYLLUM AGGREGATUM Billings.

CYSTIPHYLLOIDES sp.
Pl. 3, fig. 17

*Remarks.*—Specimens of a species of this genus are relatively abundant but very incomplete. Since the preservation is so poor and the genus is in such need of restudy, no species identifications are attempted.

*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36126.

Subclass TABULATA
Family FAVOSITIDAE
Subfamily FAVOSITINAE
Genus FAVOSITES Lamarck, 1816

*Type species.*—*F. gothlandica* Lamarck.

FAVOSITES GOLDFUSSI d'Orbigny
Pl. 5, figs. 17,18

*Favosites goldfussi* d'Orbigny, 1850, p. 107; Stewart, 1938, p. 59–60.

*Remarks.*—This is the most abundant species of tabulate coral in the Formosa reef limestone occurring in coralla up to one foot in diameter.

*Occurrence.*—Localities 6, 12.
*Type.*—Hypotype UMMP 36135.

Genus EMMONSIA Milne-Edwards & Haime, 1851

*Type species.*—*Favosites emmonsii* Rominger.

EMMONSIA EMMONSI (Rominger)
Pl. 5, figs. 15,16

*Favosites emmonsii* Rominger, 1876, p. 26.
*Emmonsia emmonsi* Stewart, 1938, p. 68.

*Remarks.*—Coralla of this species are very abundant, grow in various sizes and shapes up to 3 feet in diameter, and provide in large part the framework of the reef core.

*Occurrence.*—Localities 6, 12.
*Type.*—Hypotype UMMP 36131.

EMMONSIA BACULA (Davis)
Pl. 6, figs. 5,6

*Favosites baculus* Davis, 1887.

*Remarks.*—This species is represented by a single, badly weathered specimen which is too porous and fragile for sectioning.

*Occurrence.*—Locality 12.
*Type.*—Hypotype UMMP 36133.

EMMONSIA sp. cf. E. BACULA (Davis)
Pl. 5, figs. 1–4

*Remarks.*—Several specimens are very similar to *E. bacula* (Davis) but are too poorly preserved to be determined.

*Occurrence.*—Locality 6.
*Figured specimen.*—UMMP 36141.

EMMONSIA RADICIFORMIS (Rominger)
Pl. 6, figs. 3,4

*Favosites radiciformis* Rominger, 1876, p. 34.
*Emmonsia radiciformis* Stewart, 1938, p. 69.

*Remarks.*—This species is represented by a single poorly preserved specimen.

*Occurence.*—Locality 6.
*Type.*—Hypotype UMMP 36132.

EMMONSIA sp. cf. E. RECTANGULARIS (Grabau)
Pl. 6, figs. 1,2

*Favosites rectangularis* Grabau, 1910, p. 111–112.

*Remarks.*—The maximum diameter of the corallites averages 1.5 mm. which is slightly larger than the diameter cited by Grabau for *E. rectangularis*. Otherwise the Formosa reef limestone specimens are quite similar to Grabau's types in the Museum of Paleontology, University of Michigan.

*Occurrence.*—Localities 6, 12.
*Figured specimen.*—UMMP 36134.

Subfamily PACHYPORINAE
Genus THAMNOPORA Steininger, 1831

*Type species.*—*Alveolites cervicornis* Blainville.

THAMNOPORA LIMITARIS (Rominger)
Pl. 5, figs. 19,20

*Favosites limitaris* Rominger, 1876, p. 36–37; Stewart, 1938, p. 64.

*Thamnopora limitaris* Stumm, 1950, cards 386–389.

*Remarks.*—This species is not abundant in the Formosa reef limestone but four rather well preserved specimens have been collected.

*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36139 and 36140.

Subfamily ALVEOLITINAE
Genus CLADOPORA Hall, 1852

*Cladopora* Hall, 1852, p. 137; Stewart, 1938, p. 71.
*non Coenites* Hill & Stumm, 1956, p. F466.

*Type species.*—*Cladopora seriata* Hall.

CLADOPORA CRYPTODENS (Billings)
Pl. 5, figs. 5–7

*Alveolites cryptodens* Billings, 1859, p. 115.
*Cladopora cryptodens* Rominger, 1876, p. 50–51.

*Remarks.*—Two specimens of this species have been collected. Both are rather poorly preserved. One of these has rounded apertures, is larger and herein illustrated as more typical of the species; the other specimen has flattened apertures.

*Occurrence.*—Locality 6.

*Type*—Hypotype UMMP 36137.

CLADOPORA LABIOSA (Billings)
Pl. 5, figs. 8,9

*Alveolites labiosa* Billings, 1859, p. 114.
*Cladopora labiosa* Rominger, 1876, p. 52–53.

*Remarks.*—Several specimens of this species, all poorly preserved, have been collected from the Formosa reefs.

*Occurrence.*—Localities 6, 12.

*Type.*—Hypotype UMMP 36136.

CLADOPORA ? sp.
Pl. 5, figs. 10,11

*Remarks.*—Two very small and incomplete coralla resembling a species of this genus have been collected. Both are poorly preserved and too fragile for sectioning so no certain identification is possible.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36138.

Family AULOPORIDAE
Subfamily AULOPORINAE
Genus ROMINGERIA Nicholson, 1879

*Type species.*—*Aulopora umbellifera* Billings.

ROMINGERIA UMBELLIFERA (Billings)
Pl. 5, figs. 12–14

*Aulopora umbellifera* Billings, 1859, p. 119.
*Quenstedtia umbellifera* Rominger, 1876, p. 71.
*Romingeria umbellifera* Nicholson, 1879, p. 116; Grabau & Sherzer, 1910, p. 108, pl. 14, fig. 7; Stewart, 1938, p. 80.

*Remarks.*—This species is represented by several coralla attached to a cylindrical coenosteum of *Syringostroma cylindricum*. Most of the coralla are remarkably well preserved except for the rows of septal spinules.

*Occurrence.*—Locality 47.

*Type.*—Hypotype UMMP 36127.

Subfamily SYRINGOPORINAE
Genus SYRINGOPORA Goldfuss, 1826

*Type species.*—*S. reticulata* Goldfuss.

SYRINGOPORA HISINGERI Billings
Pl. 6, figs. 7–9

*Syringopora hisingeri* Billings, 1858, p. 172.

*Remarks.*—The small size of the corallites is the diagnostic feature of this species. In the specimens from the Formosa reef limestone, the corallites are slightly farther apart than is indicated from Billings' original description.

*Occurrence.*—Localities 6, 12.

*Type.*—Hypotype UMMP 36129.

Phylum BRYOZOA
Subphylum ECTOPROCTA
Class GYMNOLAEMATA
Order CYCLOSTOMATA
Suborder CERAMOPOROIDEA
Family FISTULIPORIDAE
Genus FISTULIPORA McCoy, 1850

*Type species.*—*F. minor* McCoy.

FISTULIPORA sp.
Pl. 6, fig. 11

*Remarks.*—Two specimens of a species of this genus have been collected. Both are too poorly preserved for an accurate species determination. The original surface of the zoaria has been destroyed so that the nature of the peristomes, diaphrams, and lunaria is unknown.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36160.

FISTULIPORA ? sp.
Pl. 6, fig. 10

*Remarks.*—A single specimen of an encrusting bryozoan was collected with both rounded and angular erect zoecial apertures and apparently without diaphrams. It is tentatively referred to this genus.

*Occurrence.*—Locality 12.

*Figured specimen.*—UMMP 36174.

Genus CHEILOTRYPA Ulrich, 1884

*Type species.*—*C. hispida* Ulrich.

CHEILOTRYPA ? sp.
Pl. 6, fig. 18

*Remarks.*—One smooth, ramose incomplete zoarium was collected. It has close, irregularly spaced, oblique zoaria. Internal structures are unknown.

*Occurrence.*—Locality 18.

*Figured specimen.*—GSC 14721.

Order CRYPTOSTOMATA
Family FENESTELLIDAE
Genus FENESTELLA Lonsdale, 1839

*Type species.*—*F. antiqua* Lonsdale.

FENESTELLA sp. cf. F. PARALLELA
Hall & Simpson
Pl. 6, fig. 17

*Fenestella parallela* Hall & Simpson, 1887, p. 107, pl. 44, figs. 8–18.

*Remarks.*—A single large frond showing only the celluliferous face was collected and compares favorably with *F. parallela.*

*Occurrence.*—Locality 6.

*Figured specimen.*—USNM 549460.

Genus POLYPORA McCoy, 1844

*Type species.*—*P. dendroides* McCoy.

POLYPORA sp.
Pl. 6, fig. 16

*Remarks.*—This genus is represented by a very poorly preserved specimen having three rows of zoecia on each branch and no median keel. No species determination is possible.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36158.

Genus SEMICOSCINIUM Prout, 1859

*Type species.*—*S. rhomboideum* Prout.

SEMICOSCINIUM sp. cf. S. GRANIFERUM
Hall & Simpson
Pl. 6, figs. 13,14

*Fenestella (Hemitrypa) granifera* Hall & Simpson 1887, p. 125, pl. 50, figs. 12–14,16.
*Semicoscinium graniferum* Stewart, 1937, card 208.

*Remarks.*—The specimen is too incomplete for a certain identification of the species. The dissepiments are remarkably wide which makes the fenestrules nearly circular in outline.

*Occurrence.*—Locality 12.

*Figured specimen.*—UMMP 36156.

SEMICOSCINIUM sp.
Pl. 6, fig. 12

*Remarks.*—This specimen is very poorly preserved but differs from *S.* sp. cf. *S. graniferum* Hall above in having less closely spaced zoecial apertures, narrower dissepiments, and more oblong fenestrules.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36155.

Family SULCORETEPORIDAE
Genus SULCORETEPORA d'Orbigny, 1849

*Type species.*—*Flustra parallela* Phillips.

SULCORETEPORA ? sp.
Pl. 6, fig. 15

*Remarks.*—This specimen is a short bifoliate stem with three rows of apertures on each flattened side and none on the edges. Slightly raised longitudinal ridges separate adjacent rows of apertures. Apparently no mesopores are present between apertures but they may have been destroyed by recrystallization.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36157.

Phylum BRACHIOPODA
Class ARTICULATA
Suborder DALMANELLOIDEA
Superfamily DALMANELLACEA
Family SCHIZOPHORIIDAE
Subfamily SCHIZOPHORIINAE
Genus SCHIZOPHORIA King, 1850

*Type species.*—*Orthis resupinata* Martin.

SCHIZOPHORIA PROPINQUA (Hall)
Pl. 7, figs. 1–6

*Orthis propinqua* Hall, 1857, p. 110; 1867, p. 43–45, pl. 5, fig. 3.

*Schizophoria propinqua* Hall & Clarke, 1892, p. 212,226.

*Remarks.*—This species is represented by one almost completely exfoliated steinkern showing the outline of the valves. In one small area near the lateral border of the pedicle valve the radiating striae and the lamellose growth lines are preserved. There is no indication of the "fine concentric striae" mentioned by Hall (1867, p. 44) but this feature is not shown on any published figures of the species and so is not considered here to be of great taxonomic significance.

*Occurrence.*—Locality 6.

*Type.*—Hypotype USNM 549461.

Suborder PENTAMEROIDEA
Superfamily PENTAMERACEA
Family PENTAMERIDAE
Subfamily GYPIDULINAE
Genus PENTAMERELLA Hall, 1867

*Type species.*—*Atrypa arata* Conrad.

PENTAMERELLA PAVILIONENSIS (Hall)
Pl. 7, figs. 7–30

*Pentamerus papilionensis* Hall, 1860, p. 86.
*Pentamerella pavilionensis* Hall, 1867, p. 377; Hall & Clarke, 1894, p. 245; Cooper, 1944, p. 305, pl. 115, figs. 16–18.

*Description.*—Shells of highly variable size and shape; small to medium for the genus, generally wider than long. Outline tending to become subquadrate but with lateral and anterior margins often evenly rounded. Posterolateral margins nearly straight; beak angle generally about 100° but in some specimens it may be as much as 140°. Ornamentation highly variable but independent of shell size.

Pedicle valve moderately to strongly convex. Beak suberect, beak ridges prominent; interarea wide, flat to slightly concave, smooth, and not covered by brachial valve except along commissure. Spondylium well developed and nearly touching the interior of the valve toward the beak; median septum low and short, commonly extending less than one-quarter the length of the valve. Surface generally multicostate with a shallow but clearly defined sulcus commencing near the anterior end of the median septum and becoming increasingly deep toward the anterior border. Costae generally well defined, low and rounded to high sharp crested, 1 to 4 (most commonly 2) in the sulcus and 2 to 5 (most commonly 3) on the flanks.

Brachial valve convex near the beak becoming nearly straight in lateral outline toward the anterior border. Interior unknown. Surface generally multicostate with a prominently raised fold commencing about one-quarter the length of the valve from the beak and becoming increasingly elevated toward the anterior border. Costae low and indistinct to high and sharp crested, 1 to 6 (most commonly 3) on the fold and 2 to 5 (most commonly 3) on the flanks.

Concentric ornamentation not prominent on either valve, consisting only of irregularly spaced growth lines usually concentrated along the anterior border. Sulcus, fold, costae, and growth lines may be poorly defined grading imperceptibly to the more clearly defined, normal condition described above.

*Remarks.*—Although this species is generally not thought to be present in pre-Hamilton rocks it is the most abundant brachiopod in the Formosa reef limestone. In view of the abundance and extreme variety in the Formosa specimens, the species is here redescribed and the concept expanded to include all the Formosa forms as well as those of the Hamilton and Tully. *P. pavilionensis* is smaller and bears fewer costae than the typical *P. arata* of the Schoharie and Onondaga in New York and is somewhat larger than *P. liorhyncha* Cooper & Cloud.

*Occurrence.*—Localities 4, 6, 12, 15, 18, 43, 52, 53.

*Types.*—Hypotypes UMMP 36234–36238 and 36322; GSC 14722, 14723; USNM 549462–549466.

PENTAMERELLA GRANDIS, n. sp.
Pl. 7, figs. 31–33

*Pentamerella arata* Hall, 1867, pl. 58, figs. 11, 12.

*Description.*—Brachial valve unknown. Pedicle valve large to very large for the genus, longer than wide. Outline tending to become subtriangular to subpentagonal with straight posterolateral margins. Beak angle about 90°. Lateral outline strongly convex with greatest curvature at beak; beak slightly incurved. Beak ridges prominent; interarea wide, slightly concave, smooth. Nature of spondylium unknown; median

septum well developed, moderately wide, very short, extending only a short distance anteriorly from the beak.

Surface multicostate with a very shallow to almost imperceptable sulcus commencing in the posterior half of the valve. Costae prominent, low and rounded, to moderately elevated and rather sharp crested, numbering 3 to 5 in the sulcus and 8 to 10 on the flanks. Concentric ornamentation inconspicuous, consisting of low, lamellose, irregularly spaced growth lines.

*Remarks.*—This species is described on the basis of two specimens, one of which (No. 2837/2, Am. Mus. Nat. Hist.) was collected from the Schoharie of New York and included by Hall (1867, pl. 58, figs. 11, '12) under the name *P. arata* (Conrad). The other specimen is from the Formosa reef limestone.

*P. grandis* is characterized by its large size, slightly incurved beak, and shallow sulcus. These features distinguish it from the typical *P. arata* (Conrad) (see Hall, 1867, pl. 58, figs. 5–8, 17,18) and *P. pavilionensis* (Hall).

*Occurrence.*—Locality 6; Schoharie formation, Clarksville, New York.

*Types.*—Holotype USNM 549469; paratype no. 2837/2, American Museum of Natural History.

Suborder STROPHOMENOIDEA
Superfamily STROPHOMENACEA
Family STROPHODONTIDAE
Subfamily STROPHODONTINAE
Genus STROPHODONTA Hall, 1852

*Type species.*—*Strophomena demissa* Conrad.

STROPHODONTA HOMOLOSTRIATA Grabau
Pl. 8, fig. 1

*Strophodonta demissa* mut. *homolostriata* Grabau, 1910, p. 126.
*Strophodonta homolostriata* Ehlers, Stumm, & Kesling, 1951, pl. 3, fig. 7.

*Remarks.*—Two specimens of this species, originally described from the Amherstburg dolomite, have been collected from the Formosa reef limestone. One specimen shows only the characteristic rounded and evenly spaced radial costae; the other, a crushed mold of the brachial valve, shows a portion of the hinge line.

*Occurrence.*—Localities 6, 12.

*Types.*—Hypotypes UMMP 36232 and 36277 (unfigured).

Genus PHOLIDOSTROPHIA Hall & Clarke, 1892

*Type species.*—*Strophomena* (*Strophodonta*) *nacrea* Hall.

PHOLIDOSTROPHIA NACREA (Hall)
Pl. 8, figs. 2,3

*Strophomena* (*Strophedonta*) *nacrea* Hall, 1857, p. 144.
*Pholidostrophia nacrea* Hall & Clarke, 1892, p. 287.

*Remarks.*—This species is represented by three specimens from the Formosa reefs.

*Occurrence.*—Localities 6, 18.

*Types.*—Hypotype UMMP 36233; GSC 14724 (unfigured).

Genus MEGASTROPHIA Caster, 1939

*Type species.*—*Strophodonta concava* Hall.

Subgenus MEGASTROPHIA (MEGASTROPHIA) Williams, 1953

*Type species.*—*Strophodonta concava* Hall.

MEGASTROPHIA (MEGASTROPHIA) PROXICOSTELLATA, n. sp.
Pl. 8, figs. 4–8

*Description.*—Shells small to moderately large for the genus, hinge line straight, mucronate; concavo-convex, curvature moderate. Lateral and anterior margins evenly rounded. Interior unknown. Pseudopunctae large, widely spaced, and arranged in radially diverging lines.

Ornamentation on both valves similar, consisting of 15 to 20 narrow, prominently elevated, sharp crested costae separated by 10 to 25 fine, rounded costellae and sharply depressed furrows. Costae persistent nearly to the beak; costellae increasing in number by intercalation anteriorly. Concentric ornamentation not prominent, consisting of low, rather sharp crested rugae and extremely fine, evenly spaced filia. Rugae appear as persistent ridges broken by the costae into numerous arching segments convex toward the beak. Filia commonly not preserved but when present form a finely reticulate network with the costellae.

*Remarks.*—This species is described primarily on the basis of ornamentation. The evenly spaced, persistent costae, the num-

erous, fine costellae, and the finer, more numerous concentric filia are the most characteristic features. Specimens are only moderately abundant in the rocks of the Formosa reef limestone.

*Occurrence.*—Localities 4, 6, 43.

*Types.*—Holotype USNM 549467, paratypes USNM 549468–549470; paratype UMMP 36240; paratype GSC 14725.

MEGASTROPHIA sp. A
Pl. 8, figs. 9,10

*Remarks.*—One brachial valve was collected from the Falls of the Teeswater River area. It resembles *M. proxicostellata* in all respects except that it is somewhat larger and is strongly geniculate about one-third the length from the anterior margin. Although the specimen is somewhat crushed along the hinge line, the geniculation appears to be a natural condition and for this reason is not included with *M. proxicostellata*. Additional collection may indicate that these geniculate forms are another species.

*Occurrence.*—Locality 43.

*Figured specimen.*—GSC 14726.

MEGASTROPHIA sp. B
Pl. 8, figs. 11,12

*Remarks.*—This very small specimen bears strong resemblances to both *M. proxicostellata* and *M.* sp. A above. However, the rugae are more prominent and found only on the posterior portion of shell, there are no fine growth lines, and the geniculation is not so pronounced as in *M.* sp. A. It is probably an immature form of either *M. proxicostellata* or *M.* sp. A.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36239.

Genus CYMOSTROPHIA Caster, 1939

*Type species*—*Leptaena stephani* Barrande.

CYMOSTROPHIA sp. A
Pl. 8, fig. 13

*Remarks.*—The strophodontid fauna of the Formosa reef limestone contains a small form of this genus similar to *C. pattersoni* (Hall) except for a much smaller size. The Formosa specimens are not abundant and are too incomplete for description as a new species.

*Occurrence.*—Localities 6, 43.

*Figured specimen.*—USNM 549471.

CYMOSTROPHIA ? sp. B
Pl. 8, fig. 14

*Remarks.*—One small and incomplete brachial valve was collected which is homeomorphic after *Pytchoglyptus virginiensis* Willard, a Middle Ordovician rafinesquinid. The internal structures are unknown; however, on the basis of external ornamentation, it is here questionably included in the genus *Cymostrophia*.

*Occurrence.*—Locality 43.

*Figured specimen.*—GSC 14727.

Genus RHYTISTROPHIA Caster, 1939

*Type species.*—*Strophodonta beckei* Hall.

RHYTISTROPHIA COOPERI, n. sp.
Pl. 8, figs. 15–18

*Description.*—Shells small to medium for the genus, hinge line straight, mucronate; brachial valve plane to slightly convex in mature specimens, pedicle valve somewhat more convex than brachial. Lateral and anterior margins evenly rounded, subsemicircular. Interior unknown.

Ornamentation similar on both valves, consisting of numerous (except near hinge line), very fine, evenly spaced radial striae, about 8 to 12 evenly rounded concentric rugae, and a great many exceedingly fine, closely spaced filia. Striae evenly elevated, rounded, of relatively constant width, nonwavy, increasing in number anteriorly by intercalation, and undulating unchanged over the rugae. Troughs between striae evenly depressed, rounded, and of about the same width as the striae. Rugae well developed and persistent near anterior margin becoming less strongly elevated and less persistent toward the beak and posterolateral margins. Filia very inconspicuous and uniformly persistent over the entire shell.

*Remarks.*—This species resembles several others of the genus *Rhytistrophia*, the differences being in degree rather than in kind. *R. cooperi* has fewer, less prominent, and less elevated rugae than *R. beckei* (Hall), the hinge line is more mucronate and the striae finer than *R. caribbeana* (Weisbord), and the striae are not wavy and are more numerous

than in *R. caribbeana columbia* Caster. *R. cooperi* is named for Dr. G. Arthur Cooper, U. S. National Museum, to whom the author is greatly indebted for checking nearly all the brachiopod generic designations in this report.

*Occurrence.*—Locality 6.

*Types.*—Holotype UMMP 36241, and paratypes UMMP 36242 and 36243; paratypes GSC 14728–14730; paratype USNM 549472.

Superfamily ORTHOTETACEA
Family SCHUCHERTELLIDAE
Subfamily SCHUCHERTELLINAE
Genus SCHUCHERTELLA Girty, 1904

*Type species.*—*Streptorhynchus lens* White.

SCHUCHERTELLA VARICOSTATA, n. sp.
Pl. 8, figs. 19–25

*Description.*—Pedicle valve of medium size for the genus, moderately convex, and somewhat inflated ahead of the beak. Outline almost semicircular, greatest width near the middle of the valve. Interarea wide, ornamented by numerous, inconspicuous, straight striae; deltidium evenly convex and prominently elevated. Interior unknown.

Radial ornamentation prominent, consisting of two orders of costae. Primary costae 12 to 16, sharply elevated, narrow crested, persistent and straight, commencing near the beak and not increasing in number toward the margins. Secondary costae highly variable, rounded, emerging by intercalation between two primary costae often closer to one than the other and appearing as an auxiliary to the adjacent primary. Secondary costae varying in number (some specimens have almost none while others have one secondary between each pair of primaries) and in prominence (some are nearly as strongly elevated as the primaries while others are merely low, inconspicuous ridges). Concentric ornamentation inconspicuous, consisting only of numerous, fine, closely spaced filia, which undulate over both the primary and secondary costae.

*Remarks.*—This species is characterized for the most part by the nature of the ornamentation, particularly the secondary costae. Their appearance as auxiliary costae on the flanks of the adjacent primaries is unknown in any other species of the genus.

Identification of the brachial valve is uncertain. However, one isolated valve is very flat and ornamented similarly to the pedicle valve. Since in most species of this genus the brachial valve is the less convex, this specimen is therefore considered as brachial. Interior unknown.

*Occurrence.*—Locality 6.

*Types.*—Holotype UMMP 36248 and paratypes UMMP 36249–36252.

SCHUCHERTELLA ? sp.
Pl. 8, fig. 26

*Remarks.*—A single interior mold of a brachial valve from the Formosa reefs differs markedly from *Schuchertella varicostata* since the costae are nearly all of about the same size. The cardinalia have been destroyed so only a tentative generic designation is possible.

*Occurrence.*—Locality 12.

*Figured specimen.*—UMMP 36253.

Suborder PRODUCTOIDEA
Superfamily PRODUCTACEA
Family PRODUCTIDAE
Subfamily PRODUCTELLINAE
Genus SPINULICOSTA Nalivkin, 1937

*Type species.*—*Productus spinulicosta* Hall.

SPINULICOSTA NAVICELLA (Hall)
Pl. 8, figs. 27–30

*Productus navicella* Hall, 1857, p. 172.
*Productella navicella* Hall, 1867, p. 156.

*Remarks.*—This species is known in the Formosa reef limestone only from rare, isolated, and incomplete pedicle valves bearing the essential characters of Hall's abbreviated original description. The spine bases in these specimens are somewhat more numerous than indicated by Hall (1867, pl. 23, figs. 3,9) and are markedly arranged in both concentric semicircular rows around the beak and in radiating curved rows from the beak to the lateral margins. In the anterior portion of the pedicle valve the concentric ornamentation is marked by the more elongated spine bases which tend to become aligned in irregular and discontinuous ridges increasing by intercalation anteriorly and by bifurcation laterally.

(*Text continued on page 27*)

(*PLATES 1–14 FOLLOW PLATE 24*)

## EXPLANATION OF PLATE 1

(All figures ×10)

FIGS. *1–3—Syringostroma probicrenulatum*, n. sp., ***1,2***, vertical and tangential sections showing the nature of laminae, pillars, galleries, and mammalons, holotype, UMMP 36187; ***3***, tangential section showing numerous, short astrorhizal tubes, paratype, UMMP 36189.

*4–6—Stromatopora proxilaminata*, n. sp., ***4,5***, vertical and tangential sections showing the close spacing of the laminae and the nature of the numerous astrorhizae diverging from the mammalons, holotype, UMMP 36177; ***6***, vertical section, paratype, UMMP 36186.

*7,10—Stromatopora densilaminata*, n. sp., vertical and tangential sections of holotype showing more widely spaced laminae with considerable secondary tissue, UMMP 36175.

*8,11—Stictostroma longitubiferum*, n. sp., vertical and tangential sections of holotype showing thick laminae and long, well developed astrorhizae, UMMP 36207.

*9,12—Syringostroma sherzeri* (Grabau), vertical and tangenital sections of hypotype showing numerous, prominent large pillars, each with 1 or 2 circlets of tubes, UMMP 36190.

*13–15—Syringostroma ambiguum*, n. sp., vertical and tangential sections showing inconspicuous laminae, pillars, and large, irregular astrorhizae, holotype, UMMP 36212.

## EXPLANATION OF PLATE 2

(All figures ×10 unless otherwise indicated)

FIGS. *1–3—Anostylostroma arvense* (Parks), ***1,2***, vertical and tangential sections showing thin laminae, pillars, and dissepiments without secondary thickening, hypotype, UMMP 36196; ***3***, vertical section showing laminae both with and without secondary thickening, hypotype, UMMP 36198.

*4–6—Anostylostroma arvense densilaminatum*, n. subsp., ***4,5***, vertical and tangential sections showing laminae, pillars, and dissepiments with considerable secondary thickening, holotype, UMMP 36192; ***6***, vertical section with abundant secondary tissue, paratype, UMMP 36194.

*7–9—Stictostroma mccannelli*, n. sp., ***7***, vertical section showing thickened laminae and pillars, paratype, UMMP 36200; ***8***, tangential section, holotype, UMMP 36199; ***9***, vertical section showing porous, three-layered laminae, paratype, UMMP 36201.

*10–14—Syringostroma cylindricum*, n. sp., ***10***, transverse section showing laminae bending up into larger pillars and irregular meshwork in axial portion of coenosteum, ***11***, transverse section showing general outline of coenosteum and shape of laminae, ×3, ***12***, longitudinal section showing larger pillars and the strand-like arrangement of the tissue in the axial portion of the coenosteum, ×3, ***13***, vertical section of outer portion of coenosteum showing arrangement of laminae and pillars, ***14***, tangential section showing astrorhizae and small galleries of the outer portion of the coenosteum, holotype, UMMP 36210.

## EXPLANATION OF PLATE 3

FIGS. *1–3—Disphyllum* sp. A, ***1,3***, longitudinal sections showing wide tabularium and narrow dissepimentarium, ×1½, ***2***, transverse section, ×1½, UMMP 36118.

*4–6—Cylindrophyllum* sp. cf. *C. propinquum* Stewart, ***4***, transverse section, ×1½, UMMP 36115; ***5***, longitudinal section, ×1½, ***6***, transverse section showing carinate septa, ×1½, UMMP 36114.

*7,8—Cylindrophyllum* sp. cf. *C. elongatum* Simpson, ***7***, longitudinal section, ×1½, ***8***, transverse section, ×1½, UMMP 36142.

*9,10—Disphyllum* sp. B, ***9***, longitudinal section, ×1½, ***10***, transverse section, ×1½, UMMP 36119.

*11–14—Synaptophyllum grabaui*, n. sp., ***11,12***, longitudinal and transverse sections, ×1½, hypotype, UMMP 36117; ***13,14***, longitudinal and transverse sections, ×1½, hypotype, UMMP 36116.

*15,16—Eridophyllum seriale* Milne-Edwards and Haime, ***15***, longitudinal section, ×1½, ***16***, transverse section showing closed aulos, ×1½, hypotype, UMMP 36122.

*17—Cystiphylloides* sp., exterior view of natural longitudinal section, ×1, UMMP 36126.

*18–20—Acinophyllum mclareni*, n. sp., ***18,19***, longitudinal sections, ×1½, ***20***, transverse section of several corallites, ×1½, holotype UMMP 36120.

*21–23—Ehlersospongia stellata*, n. sp., ***21***, exterior view showing rhombic ossicles with depressed pit in center and radiating "septa," ×7, ***22***, lateral view, ×1, ***23***, view of apex showing spiral arrangement of ossicles, ×1, holotype, UMMP 36111.

*24—Receptaculites* sp., exterior view showing gridlike arrangement of ossicles, ×7, UMMP 36112.

## Explanation of Plate 4

FIGS. *1,2—Heliophyllum* sp. cf. *H. verticale* Hall, *1*, longitudinal section, ×1½, *2*, transverse section, ×1½, UMMP 36143.

*3—Zaphrentis* sp., exterior view of an incomplete calyx showing denticulate septa, ×1, UMMP 36128.

*4—Blothrophyllum* sp., transverse section showing lonsdaleioid dissepimentarium and retreat of septa from periphery, ×1½, UMMP 36113.

*5—Siphonophrentis gigantea* Lesueur, exterior view of natural longitudinal section showing down warped tabulae in the cardinal fossula, ×1, hypotype, UMMP 36146.

*6—Siphonophrentis* sp., exterior view of incomplete corallite showing amplexoid septa and downwarped tabulae in the cardinal fossula, ×1, UMMP 36147.

*7—Heterophrentis ?* sp., transverse section showing alternating long and short septa, ×1½, UMMP 36130.

*8,9—Heliophyllum* sp., *8*, longitudinal section, ×1½, *9*, transverse section, ×1½, UMMP 36145.

*10,11—Heliophyllum* sp. cf. *H. incrassatum* Hall, *10*, longitudinal section, ×1½, *11*, transverse section showing slightly dilated septa, ×1½, UMMP 36144.

*12,13—Depasophyllum ?* sp., *12*, longitudinal section, ×1½, *13*, transverse section, ×1½, UMMP 36123.

*14—Depasophyllum* sp. cf. *D. adnetum* Grabau, exterior view of natural longitudinal section showing "pill box" tabulae, ×1, UMMP 36124.

*15—Placophyllum ?* sp., exterior view of natural longitudinal section showing flat, complete tabulae and short septal ridges, ×1, UMMP 36125.

## Explanation of Plate 5

FIGS. *1–4—Emmonsia* sp. cf. *E. bacula* (Davis), *1,4*, exterior views of nearly complete coralla, ×1, *2*, longitudinal section showing poorly developed squamulae, ×3, *3*, transverse section, ×3, UMMP 36141.

*5–7—Cladopora cryptodens* (Billings), *5*, exterior view showing irregularly spaced corallities, ×2, *6*, transverse section, ×3, *7*, longitudinal section, ×3, hypotype, UMMP 36137.

*8,9—Cladopora labiosa* (Billings), *8*, transverse section, ×3, *9*, longitudinal section, ×3, hypotype, UMMP 36136.

*10,11—Cladopora ?* sp., exterior views, ×4, UMMP 36138.

*12–14—Romingeria umbellifera* (Billings), *12*, exterior of several incomplete coralla showing umbellate arrangement of corallites, ×1, *13*, longitudinal section showing method of branching of corallites from main axis, ×1½, 14, transverse section, ×1½, hypotype, UMMP 36127.

*15,16—Emmonsia emmonsi* (Rominger), *15*, longitudinal section showing mural pores and squamulae, ×1½, *16*, transverse section, ×1½, hypotype, UMMP 36131.

*17,18—Favosites goldfussi* d'Orbigny, *17*, longitudinal section showing mural pores and variable spacing of tabulae, ×1½, *18*, transverse section, ×1½, hypotype, UMMP 36135.

*19,20—Thamnopora limitaris* (Rominger), *19*, exterior view showing thickening of corallite walls around apertures, ×2, *20*, transverse section also showing peripherally thickened corallite walls, ×1½, hypotype, UMMP 36139.

## Explanation of Plate 6

FIGS. *1,2—Emmonsia* sp. cf. *E. rectangularis* (Grabau), *1*, exterior view of natural longitudinal section showing arrangement of corallites, ×1, *2*, longitudinal section, ×1½, UMMP 36134.

*3,4—Emmonsia radiciformis* (Rominger), *3*, transverse section showing larger circular corallites and smaller angular corallites, ×1½, *4*, longitudinal section, ×1½, hypotype, UMMP 36132.

*5,6—Emmonsia bacula* (Davis), *5*, exterior view, ×1, *6*, longitudinal view, ×3, hypotype, UMMP 36133.

*7–9—Syringopora hisingeri* Billings, *7*, transverse section, ×3, *8*, longitudinal section showing stolons and axial tubes, ×3, *9*, exterior view of closely packed corallites, ×2, hypotype, UMMP 36129.

*10—Fistulipora ?* sp., exterior view of zoarium showing rounded and angular zoecial apertures, ×6, UMMP 36174.

*11—Fistulipora* sp., exterior view of zoarium, ×6, UMMP 36160.

*12—Semicoscinium* sp., exterior view showing expanded median keel between rows of fenestrules, ×6, UMMP 36155.

*13,14—Semicoscinium* sp. cf. *S. graniferum* Hall and Simpson, *13*, exterior view showing arrangement of zoecia and fenestrules, ×6, *14*, exterior view showing expanded median keel between rows of fenestrules, ×6, UMMP 36156.

*15—Sulcoretepora ?* sp., exterior view showing zoecia in rows separated by raised ridges, ×6, UMMP 36157.

*16*—*Polypora* sp., exterior view showing 3 rows of zoecia on each branch, ×6, UMMP 36158.
*17*—*Fenestella* sp. cf. *F. parallela* Hall and Simpson, exterior view showing double rows of zoecia on each branch, ×6, USNM 549460.
*18*—*Cheilotrypa ?* sp., exterior view of incomplete zoarium, ×6, GSC 14721.

## Explanation of Plate 7

(All figures ×1 unless otherwise indicated)

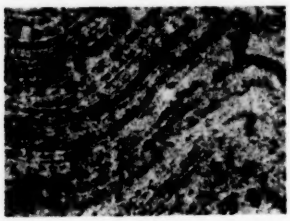
Figs. *1–6*—*Schizophoria propinqua* (Hall), *1*, brachial valve, *2*, pedicle valve, *3*, side view, *4*, posterior view, *5*, anterior view, *6*, close-up ornamentation, ×5, hypotype, USNM 549461.
*7–30*—*Pentamerella pavilionensis* (Hall), *7*, brachial valve, *8*, pedicle valve, *9*, side view, *10*, posterior view, *11*, anterior view, hypotype, UMMP 36235; *12*, brachial valve, *13*, pedicle valve, *14*, side view, *15*, anterior view, *16*, posterior view, hypotype, UMMP 36234; *17*, brachial valve with fold but without costae, hypotype, UMMP 36236; *18*, pedicle valve with 1 costa in sulcus and 4 costae on flanks, hypotype, USNM 549464; *19*, interior of small pedicle valve showing spondylium, ×2, *20*, pedicle valve with one costa in sulcus and 2 on flanks, hypotype, USNM 549462; *21*, brachial valve with 2 low, rounded costae on fold and smooth flanks, hypotype, USNM 549465; *22*, pedicle valve showing 2 sharp crested, prominent costae on fold and 2 costae on flanks, *23*, oblique anterior view of pedicle valve, hypotype, GSC 14722; *24*, pedicle valve, *25*, oblique anterior view showing 3 costae on fold and 2 costae on flanks, hypotype, UMMP 36322; *26*, brachial view with 5 low costae on fold and 4 low costae on flanks, *27*, pedicle valve showing very shallow sulcus with 4 costae and 4 costae on flanks, hypotype, UMMP 36237; *28*, pedicle valve with 4 non-persistent costae in sulcus and 4 costae on flanks, hypotype, UMMP 36238; *29*, brachial valve with 4 costae on fold and 5 costae on flanks, hypotype, USNM 549463; *30*, pedicle valve with 2 costae in deep sulcus and 3 costae on flanks, hypotype USNM 549466.
*31–33*—*Pentamerella grandis*, n. sp., *31*, oblique view of beak, *32*, pedicle view, *33*, side view, holotype, a pedicle valve, USNM 549469.

## Explanation of Plate 8

(All figures ×1 unless otherwise indicated)

Figs. *1*—*Strophodonta homolostriata* Grabau, partially exfoliated brachial valve, hypotype, UMMP 36232.
*2,3*—*Pholidostrophia nacrea* (Hall), *2*, brachial valve, *3*, side view of brachial valve, hypotype, UMMP 36233.
*4–8*—*Megastrophia* (*Megastrophia*) *proxicostellata*, n. sp., *4*, brachial valve, *5*, close-up of rugae, ×2, *6*, close-up showing fine reticulate pattern formed by costellae and filia, ×5, holotype USNM 549467; *7*, close-up of pedicle valve showing costellae and pseudopunctae, ×5, paratype, UMMP 36240; *8*, small, somewhat crushed and distorted brachial valve, paratype, GSC 14725.
*9,10*—*Megastrophia* sp. A, *9*, brachial valve, *10*, side view of brachial valve showing geniculate profile, GSC 14726.
*11,12*—*Megastrophia* sp. B, *11*, brachial valve showing rugae only in posterior portion, *12*, side view, UMMP 36239.
*13*—*Cymostrophia* sp. A, brachial valve, USNM 549471.
*14*—*Cymostrophia ?* sp. B, brachial valve, GSC 14727.
*15–18*—*Rhytistrophia cooperi*, n. sp., *15*, brachial valve, *16*, close-up showing nature of striae, ×5, holotype, UMMP 36241; *17*, a small brachial valve, paratype UMMP 36242; *18*, incomplete brachial valve showing mucronate hinge line, paratype, USNM 549472.
*19–25*—*Schuchertella varicostata*, n. sp., *19*, pedicle valve showing auxiliary secondary costae, *20*, interarea and deltidium, *21*, side view showing elevated beak with flattened top, holotype, UMMP 36248; *22*, close-up of anterior portion showing filia, ×5, *23*, flat brachial valve, paratype, UMMP 36251; *24*, pedicle valve showing evenly spaced primary and secondary costae, paratype, UMMP 36249; *25*, small pedicle valve with poorly developed secondary costae, ×3, paratype, UMMP 36252.
*26*—*Schuchertella ?* sp., mold of interior of brachial valve, UMMP 36253.
*27–30*—*Spinulicosta navicella* (Hall), *27*, pedicle valve showing elongated spine bases, *28*, side view of pedicle valve, *29*, oblique view of beak showing concentric and radiating pattern of small spine bases, ×2, *30*, posterior view of pedicle valve, hypotype, UMMP 36245.

(*See Explanation of* Plates 9–14 *on pages 25–27*)



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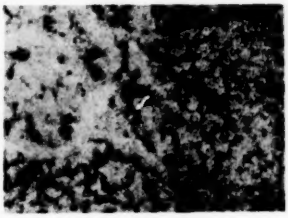

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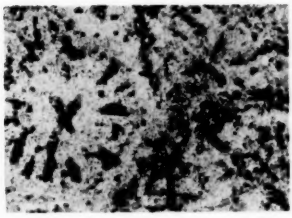

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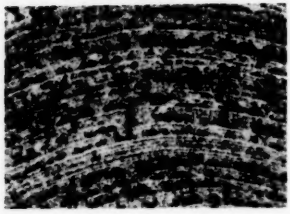

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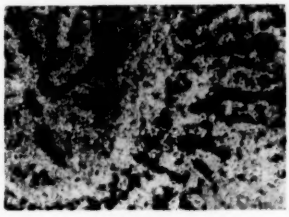

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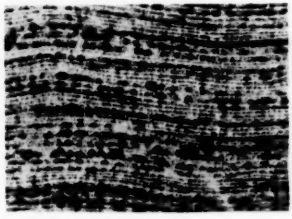

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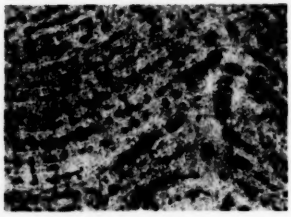

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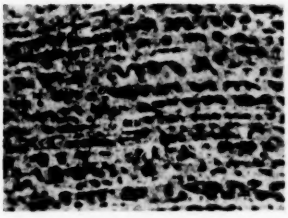

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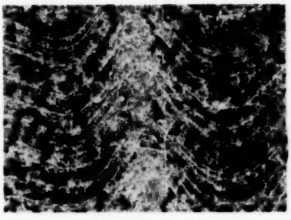

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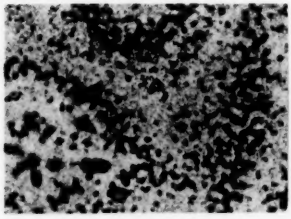

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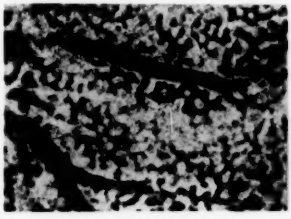

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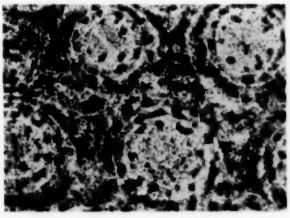

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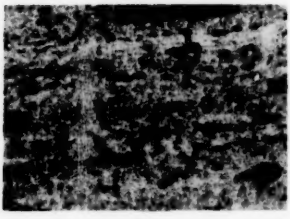

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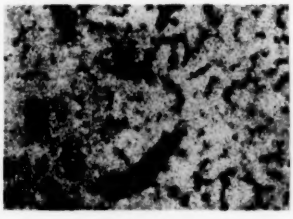

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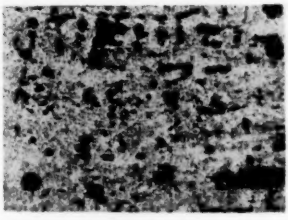

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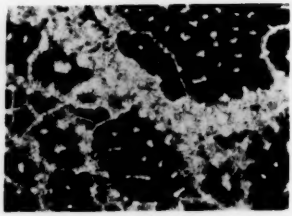

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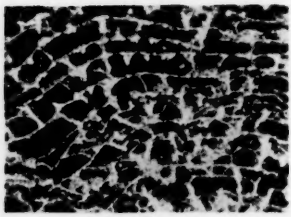

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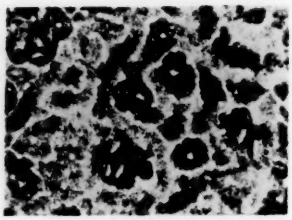

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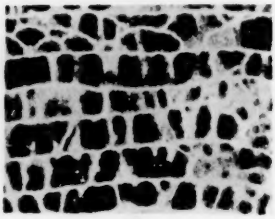

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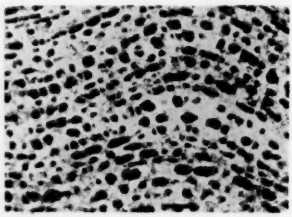

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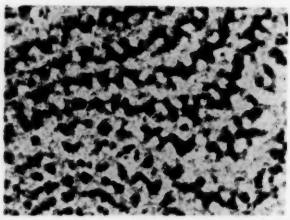

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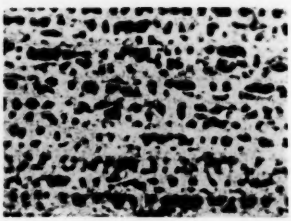

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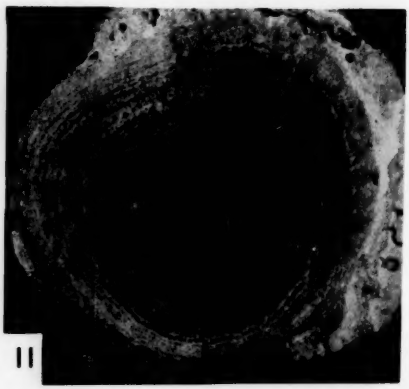

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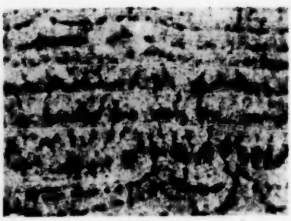

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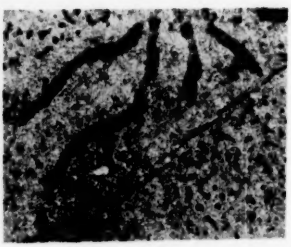

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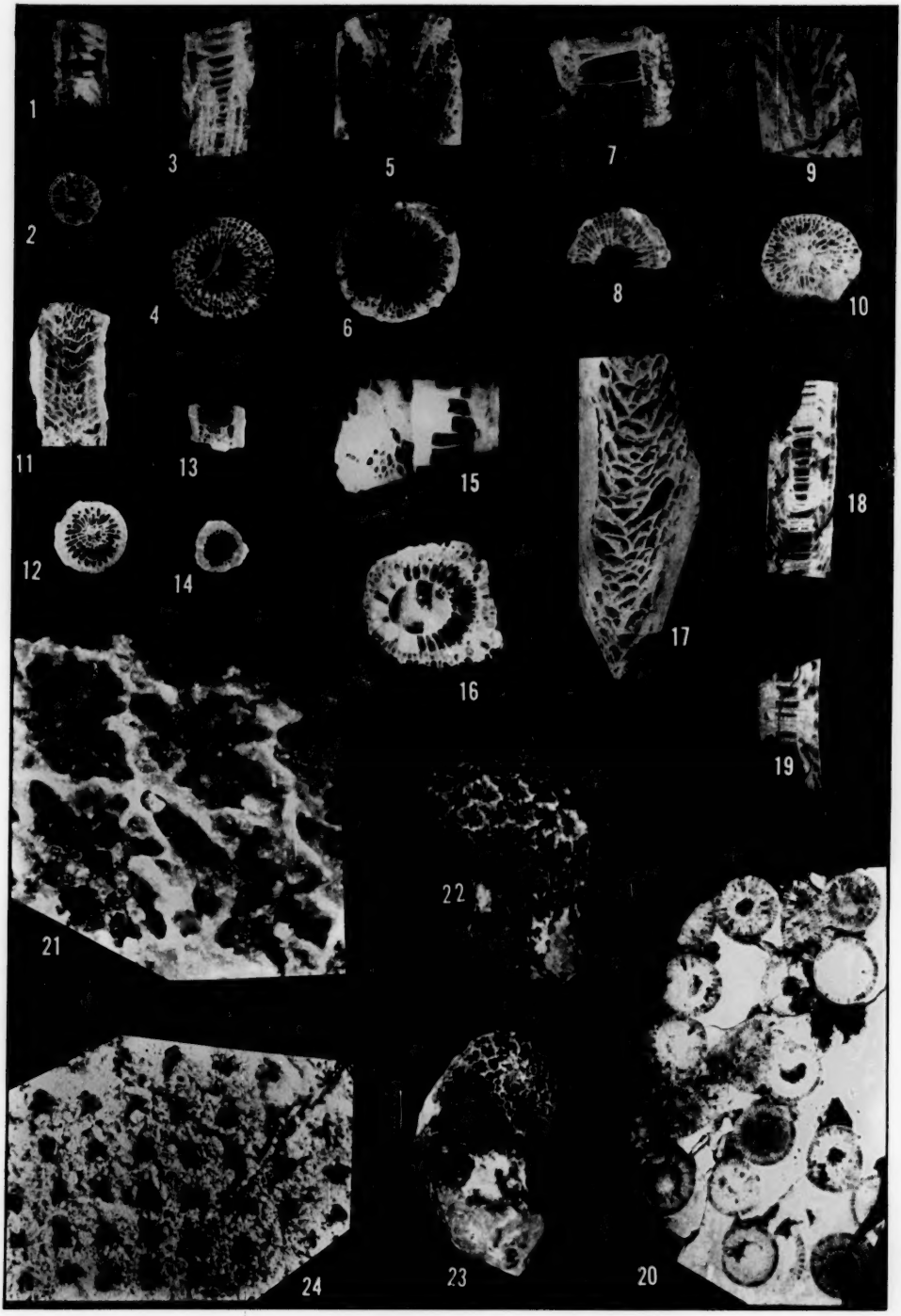
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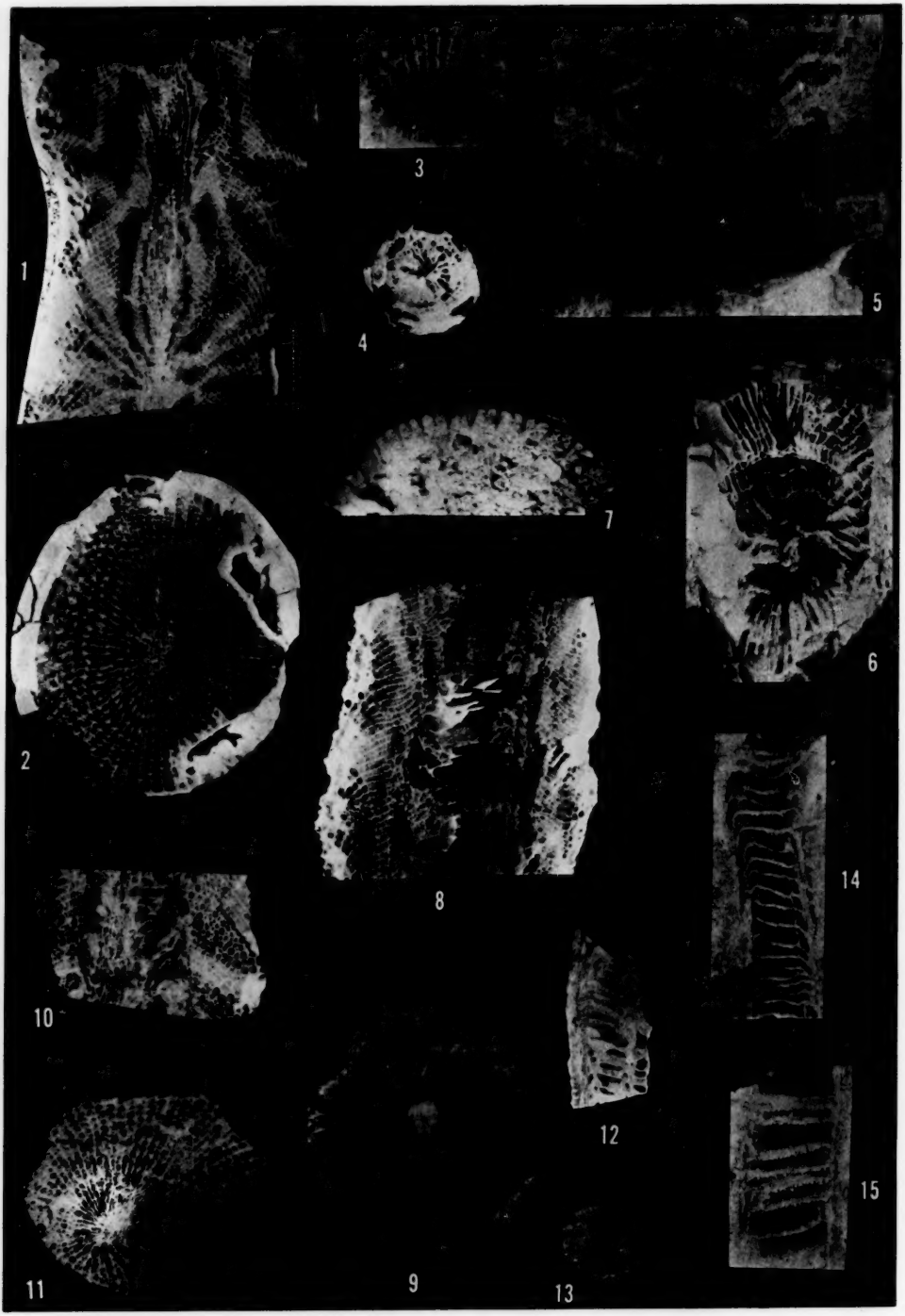
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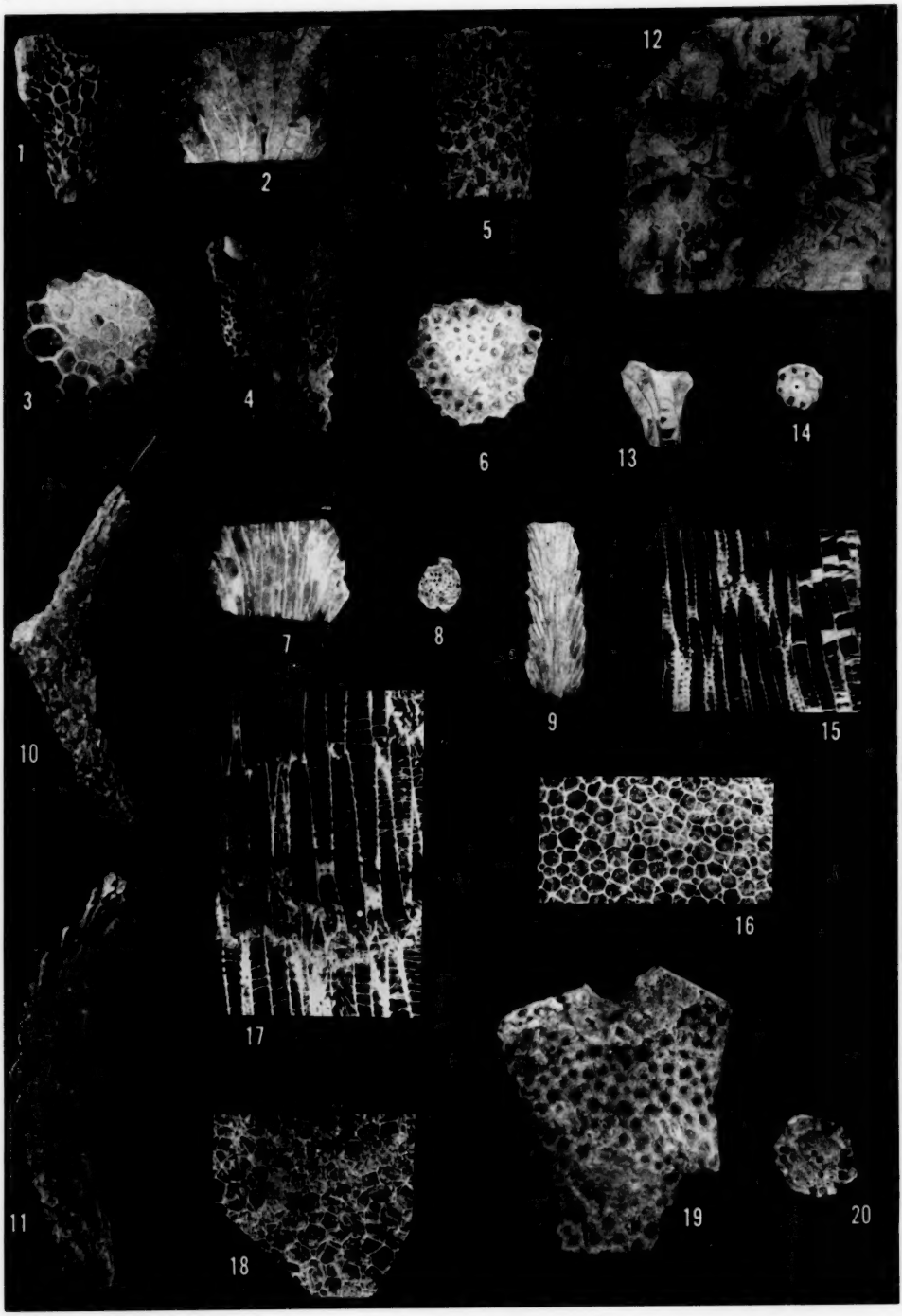
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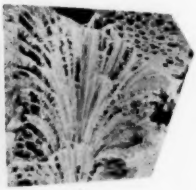
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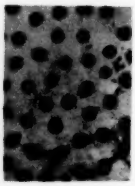
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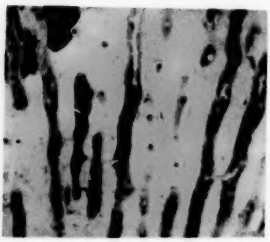
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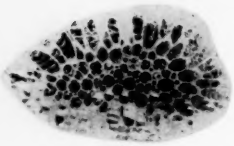
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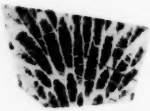
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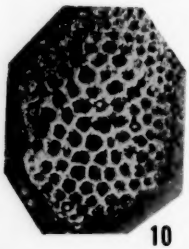
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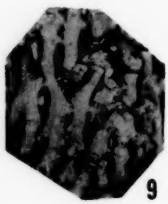
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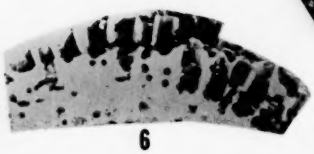
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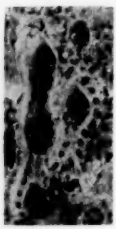
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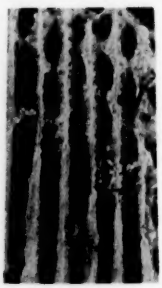
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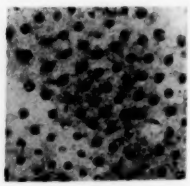
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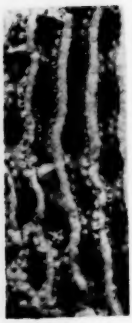
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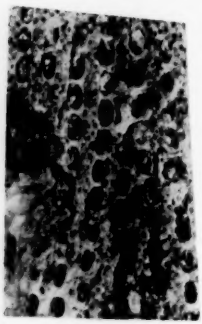
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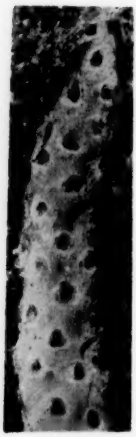
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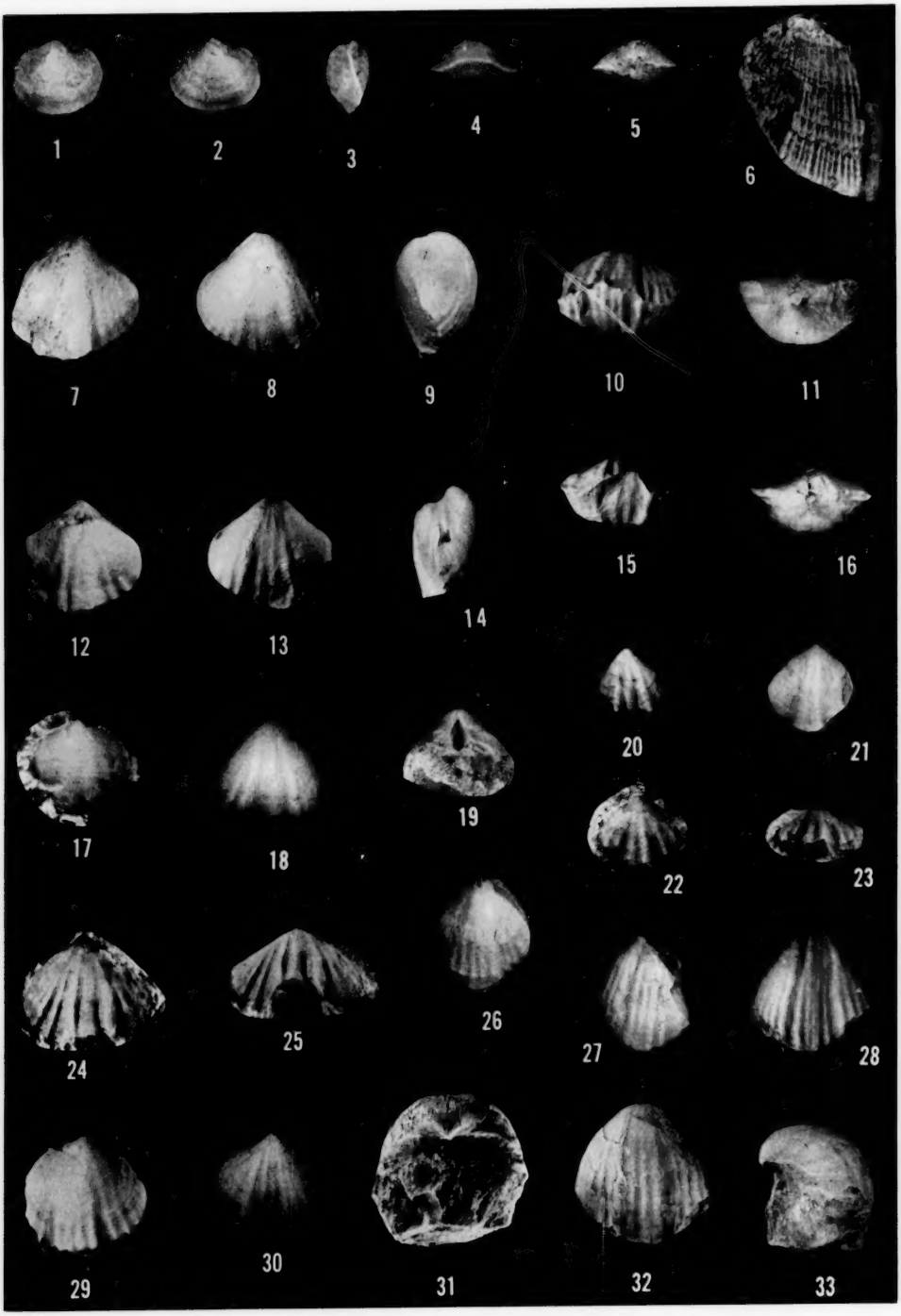
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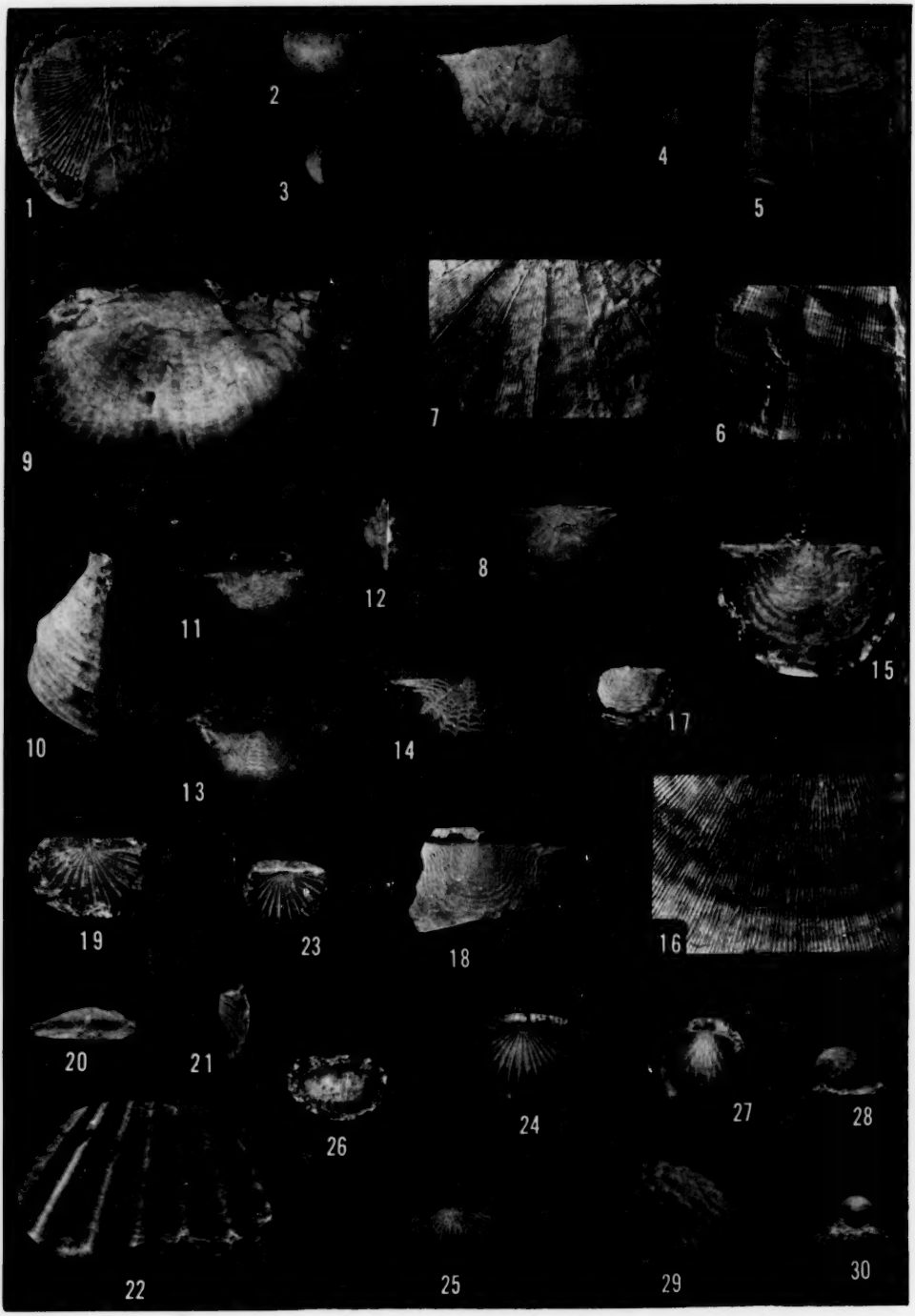
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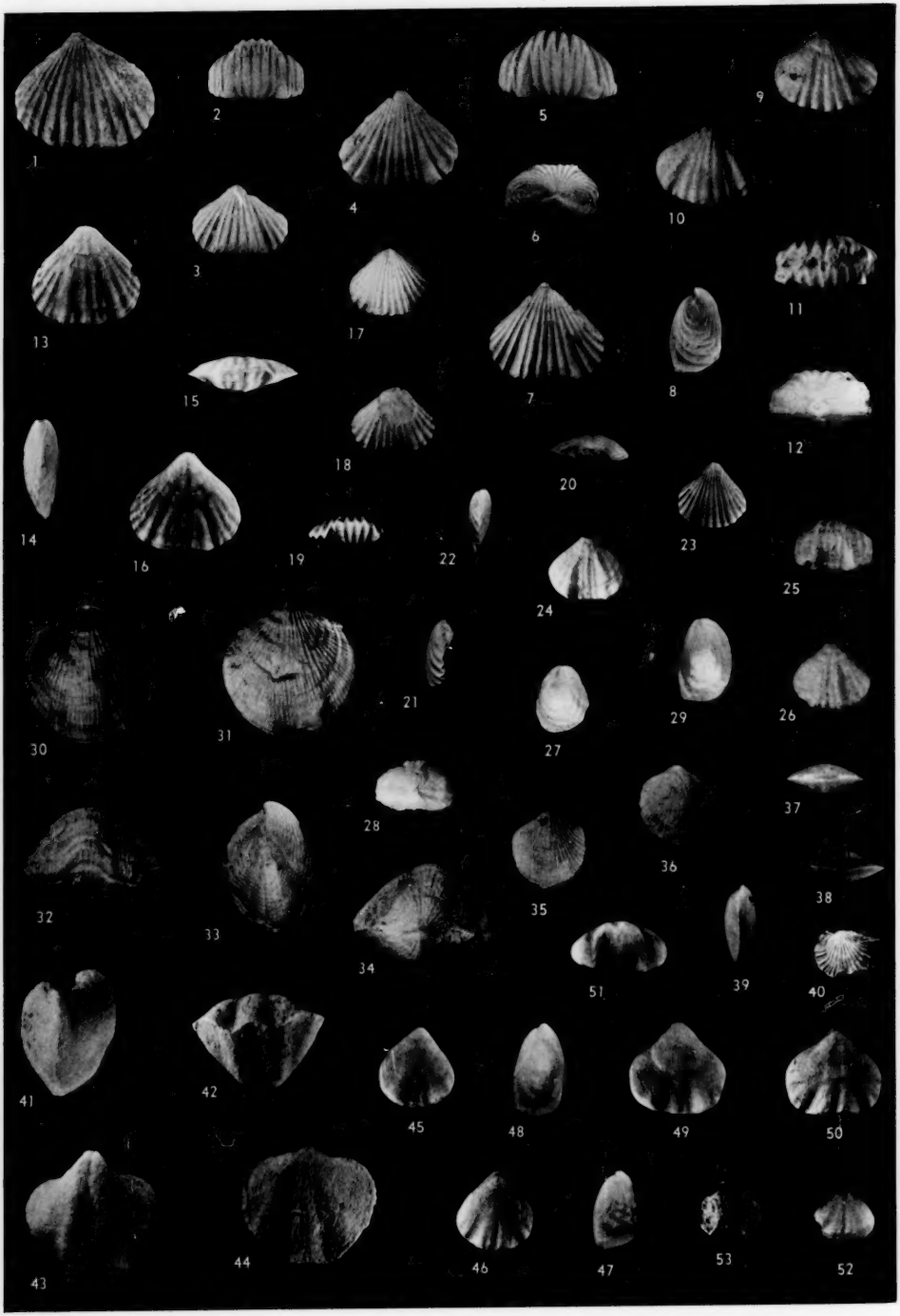
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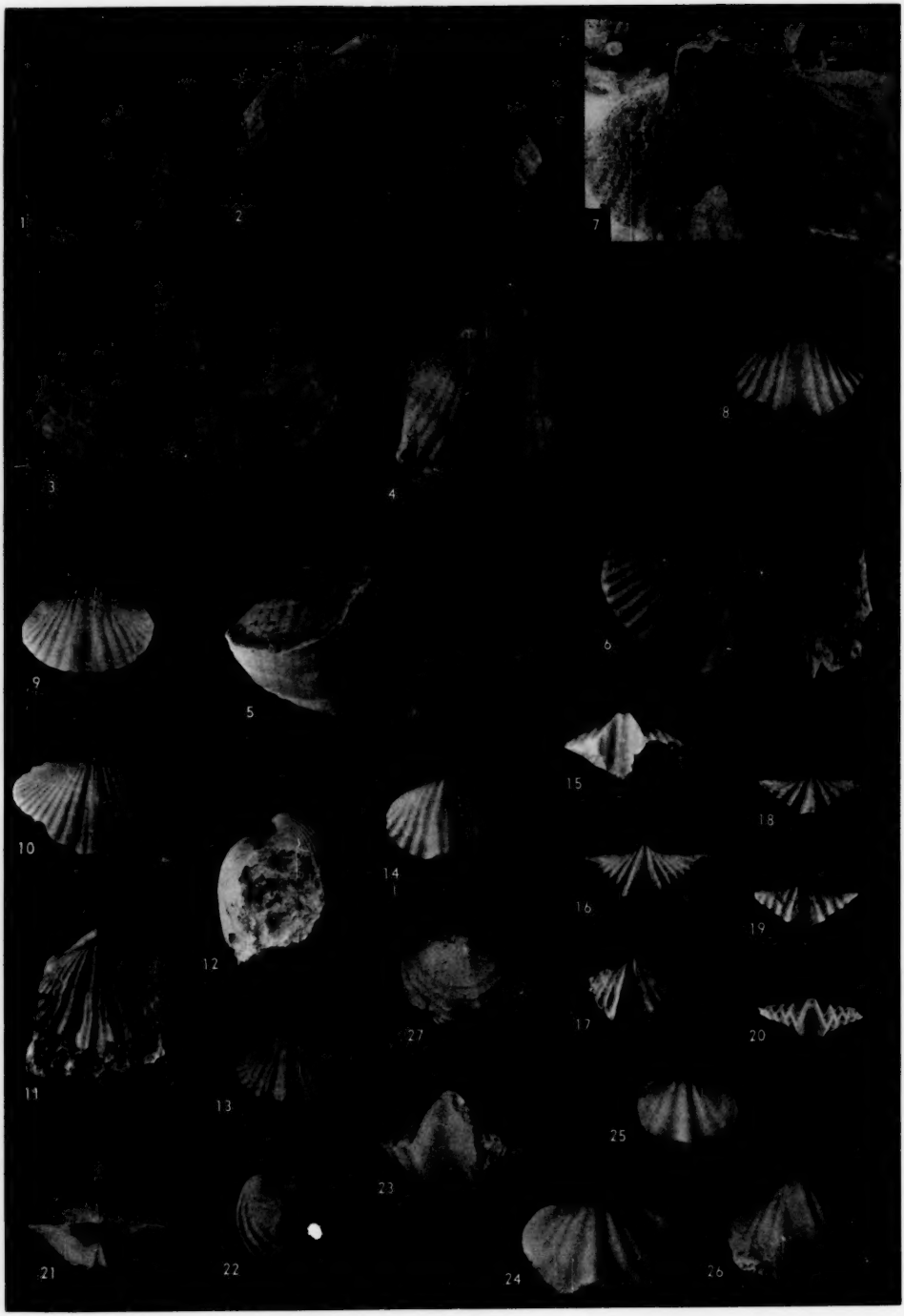
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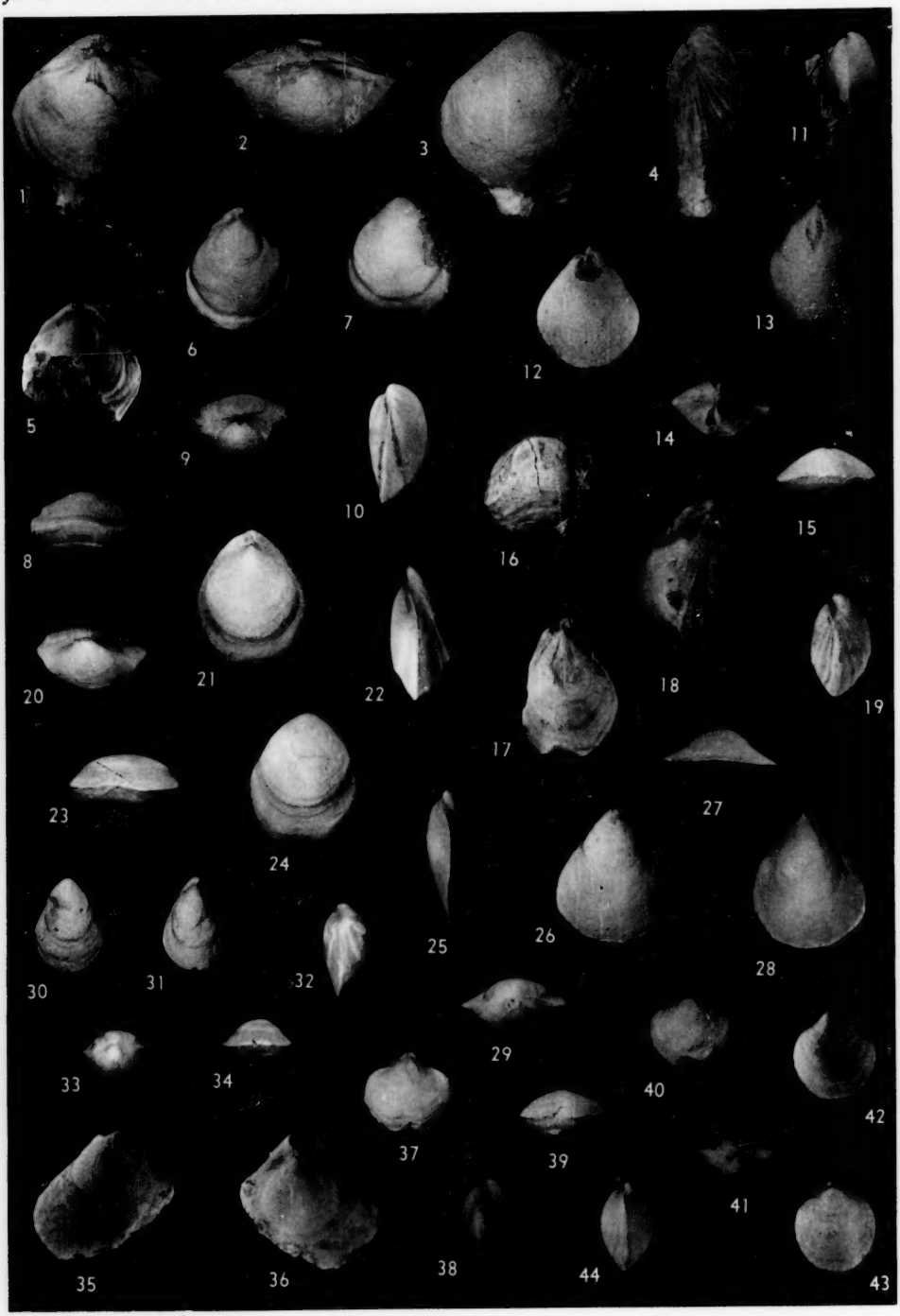
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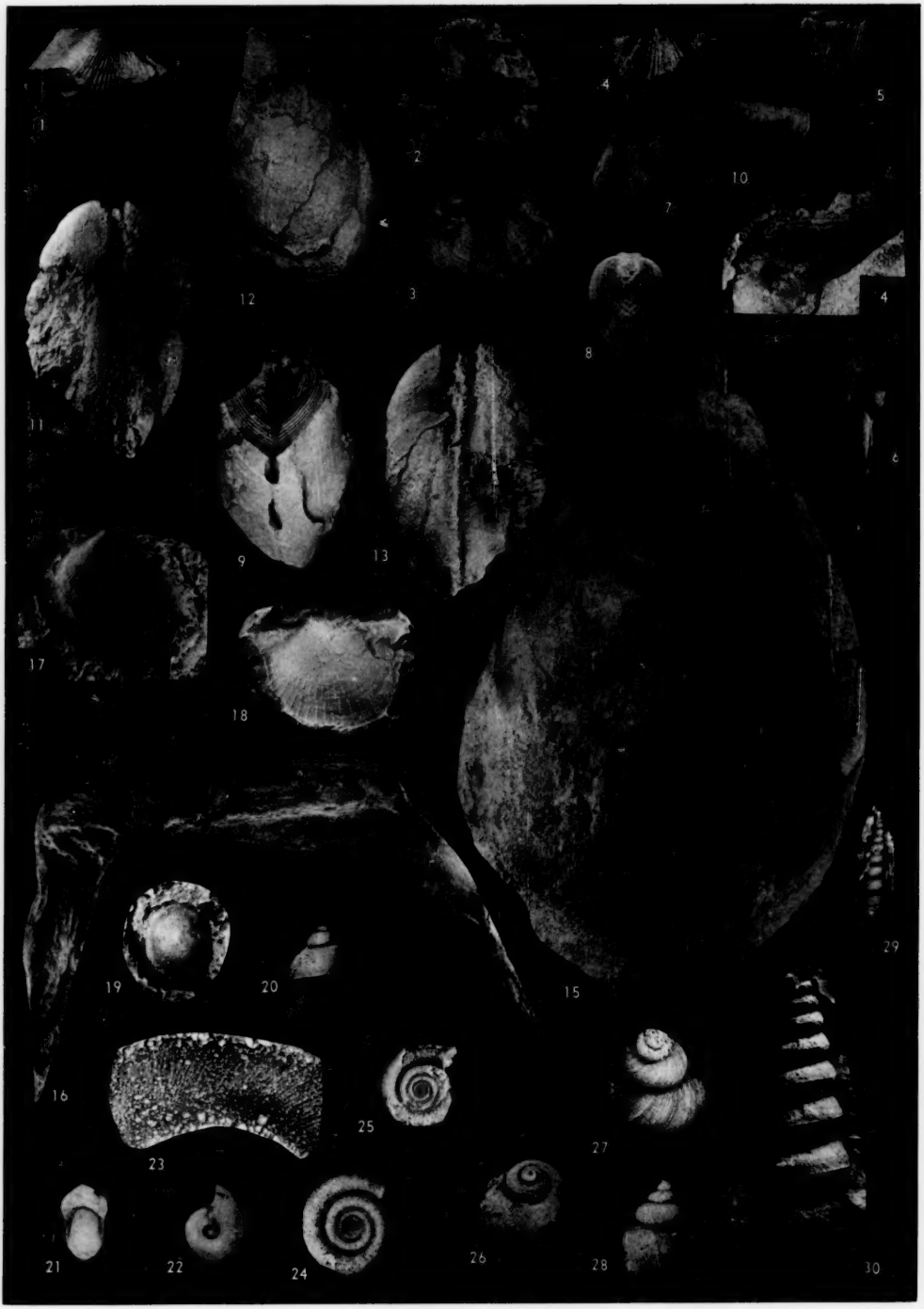
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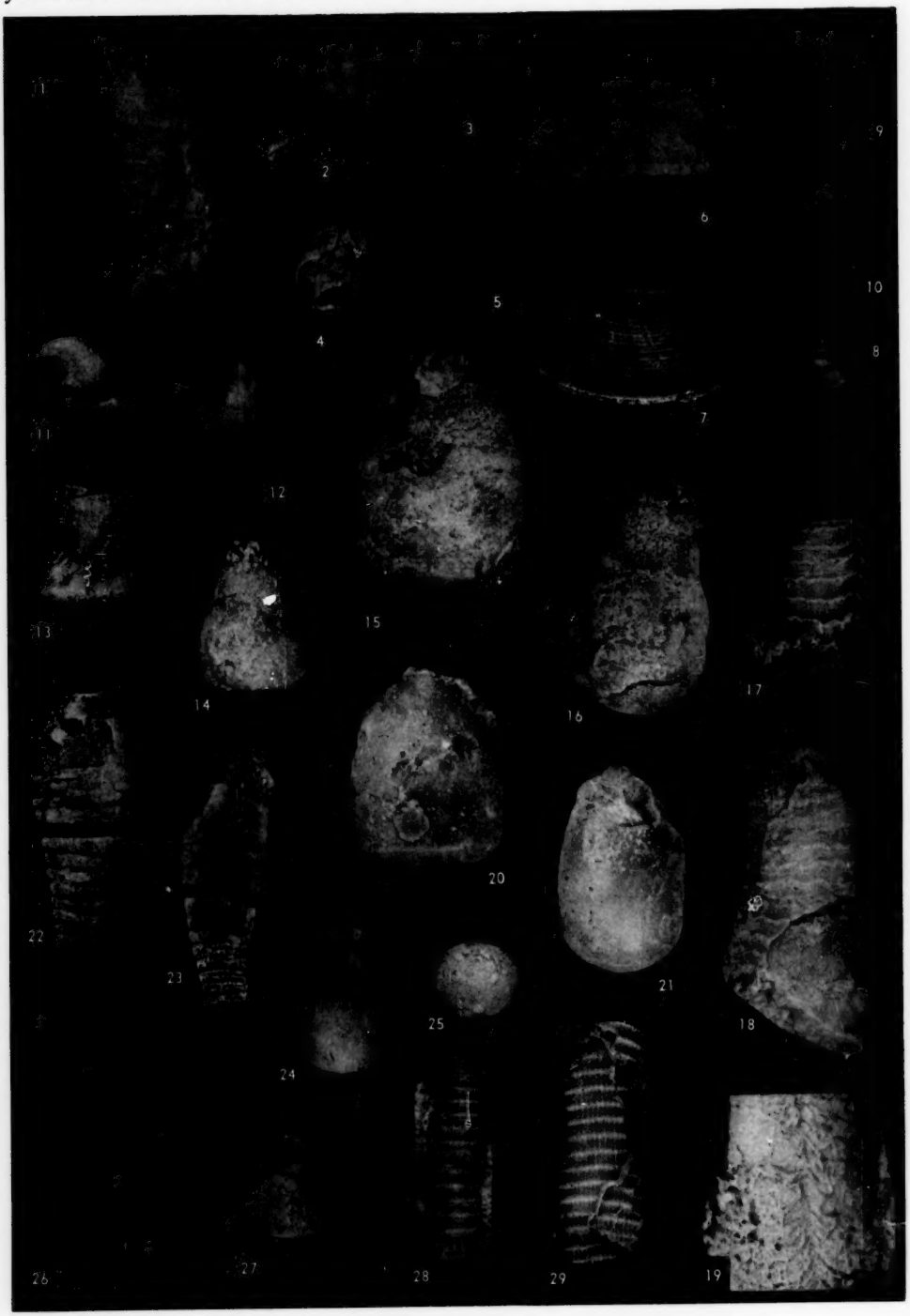
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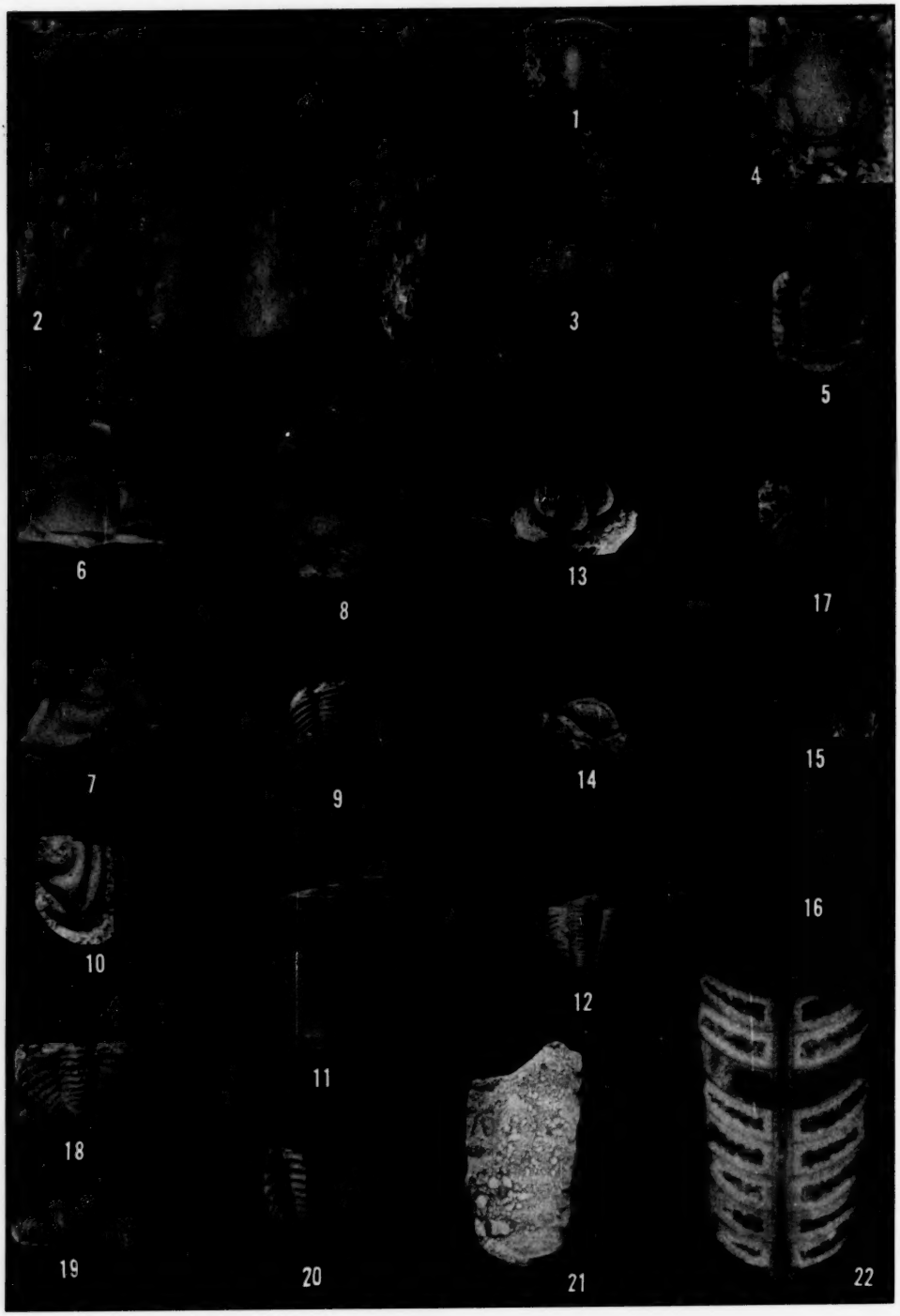
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## Explanation of Plate 9

(All figures ×1 unless otherwise indicated)

Figs. *1–12—Camarotoechia tethys* (Billings), *1*, brachial view of large specimen, hypotype, UMMP 36261; *2*, anterior view, *3*, brachial view, hypotype, UMMP 36260; *4*, pedicle view, *5*, anterior view, *7*, brachial view, hypotype, USNM 549473; *6*, posterior view, *8*, side view, hypotype, UMMP 36259; *9*, brachial view, *10*, pedicle view, *11*, anterior view, *12*, posterior view, hypotype, UMMP 36264.

*13–16—Camarotoechia ambigua*, n. sp., *13*, pedicle view, *14*, side view, *15*, anterior view, *16*, brachial view; ×2, holotype, UMMP 36265.

*17–23—Camarotoechia formosensis*, n. sp., *17*, brachial view, *18*, pedicle view, *19*, anterior view, *20*, posterior view, *21*, side view, holotype, UMMP 36262; *22*, side view, *23*, pedicle view, paratype, USNM 549474.

*24–29—Camarotoechia lamellosa*, n. sp., *24*, pedicle view, *25*, anterior view, *26*, brachial view, *27*, side view, *28*, posterior view, holotype, UMMP 36263; *29*, side view, paratype, GSC 14733.

*30–34—Atrypa* sp. B, *30*, brachial view, *31*, pedicle view, *32*, anterior view, *33*, side view, *34*, posterior view, UMMP 36276.

*35–40—Atrypa* sp. A, *35*, pedicle view, *36*, brachial view, *37*, posterior view, *38*, anterior view, *39*, side view, UMMP 36275; *40*, brachial view of small specimen showing frill, ×2, USNM 549478.

*41–44—Metaplasia uniplicata*, n. sp., *41*, side view, *42*, anterior view, *43*, pedicle view, *44*, brachial view, ×5, holotype, USNM 549479.

*45–47—Stenoscisma rhomoidalis* (Hall & Clarke), *45*, pedicle view, *46*, brachial view, *47*, side view, ×2, hypotype, GSC 14734.

*48–51—Stenoscisma halli*, n. sp., *48*, side view, *49*, pedicle view, *50*, brachial view, *51*, anterior view, ×2, holotype, USNM 549477.

*52,53—Stenoscisma* sp., *52*, brachial view, *53*, anterior view, UMMP 36274.

## Explanation of Plate 10

(All figures ×1 unless otherwise indicated)

Figs. *1–7—Fimbrispirifer divaricatus* (Hall), *1*, side view, *4*, pedicle view, *6*, brachial view, hypotype, UMMP 36286; *2*, brachial view, *3*, pedicle view, *5*, anterior view, hypotype, UMMP 36285; *7*, view of cast of interior of pedicle valve showing dental plates, myophragm and spine bases, ×2, hypotype, UMMP 36288.

*8—"Spirifer"* sp. A, pedicle valve, UMMP 36300.

*9–13—Fimbrispirifer tricostatus*, n. sp., *9*, pedicle valve showing 3 costae in sulcus, paratype, GSC 14738; *10*, brachial view showing median furrow on posterior portion of fold and median ridge on anterior portion, hypotype, GSC 14737; *11*, brachial view showing prominent tri-costate median ridge, *12*, side view, holotype, UMMP 36295; *13*, brachial valve, paratype, UMMP 36297.

*14,15—"Spirifer"* sp. B, *14*, brachial view, *15*, anterior view, UMMP 36301.

*16–20—Kozlowskiellina* (*Megakozlowskiella*) *submersa* (Grabau), *16*, pedicle view, hypotype, UMMP 36279; *17*, pedicle valve, hypotype, UMMP 36280; *18*, brachial view, *19*, pedicle view, *20*, anterior view, hypotype, UMMP 36284.

*21–26—Elytha formosensis*, n. sp., *21*, posterior view, *22*, side view, *23*, anterior view, *24*, brachial view, *26*, pedicle view, holotype, USNM 549483; *25*, brachial view, paratype, UMMP 36302.

*27—Athyris cora* Hall, pedicle view, hypotype, USNM 549492.

## Explanation of Plate 11

(All figures ×1 unless otherwise indicated)

Figs. *1–4—Meristella nasuta* (Conrad), *1*, brachial view, *2*, posterior view, *3*, pedicle view, *4*, side view, hypotype, UMMP 36303.

*5–10—Meristella barrisi* Hall, *5*, brachial view showing numerous, prominent growth lines along anterolateral margin, hypotype, UMMP 36308; *6*, brachial view, *7*, pedicle view, *8*, anterior view, *9*, posterior view, *10*, side view, hypotype, UMMP 36307.

*11–15—Meristella formosensis*, n. sp., *11*, side view, paratype, UMMP 36310; *12*, pedicle view, *13*, brachial view, *14*, posterior view showing laterally convex dental plates joining above the thickened muscle attachment area and V-shaped dorsal cruralium, *15*, anterior view, holotype, USNM 549488.

*16–19—Meristella angustisinuata*, n. sp., *16*, anterior view showing narrow, sharply elevated fold, *18*, side view, paratype, USNM 549489; *17*, brachial view showing cruralium, holotype, GSC 14742; *19*, side view, paratype, USNM 549490.

*20–24—Cranaena romingeri* (Hall), *20*, posterior view, *21*, brachial view, *22*, side view, *23*, anterior view, *24*, pedicle view, ×2, hypotype, UMMP 36318.

*25–29—Cryptonella lens* (Hall), *25*, side view, *26*, pedicle view, *27*, anterior view, *28*, brachial view, *29*, posterior view showing large, circular foramen, ×2, hypotype, UMMP 36320.
*30–34—Meristella subrotunda*, n. sp., *30*, pedicle view, *31*, brachial view, *32*, side view, *33*, posterior view, *34*, anterior view, holotype, UMMP 36311.
*35,36—Camarospira* sp., *35*, pedicle view, *36*, brachial view, UMMP 36313.
*37–41—Athyris cora* Hall, *37*, brachial view, *38*, side view, *39*, anterior view, *40*, pedicle view, *41*, posterior view, hypotype, UMMP 36315.
*42–44—Athyris minuta*, n. sp., *42*, pedicle view, *43*, brachial view, *44*, side view, ×2, holotype, USNM 549500.

## Explanation of Plate 12

(All figures ×1 unless otherwise indicated)

Figs. *1–3,9—Conocardium cuneus* (Conrad), *1*, lateral view, hypotype, UMMP 36164; *2,3*, mold and rubber cast of anterior end showing hollow tube between halves in hood, *9*, oblique view of hood with hollow tube, hypotype, UMMP 36165.
*4–6—Conocardium ohioense* Meek, *4,5*, lateral views of hypotypes GSC 14748, and UMMP 36161, respectively; *6*, dorsal view of rubber cast, hypotype, UMMP 36162.
*7,8—Conocardium* sp., *7*, lateral view, ×2, *8*, anterior view, ×3, UMMP 36167.
*10—"Sanguinolites"* sp., lateral view of left valve, UMMP 36168.
*11–16*—Genus A sp. A, *11*, posterior view, *12*, left valve showing partially exfoliated surface with outline of growth lines, *13*, anterior view, UMMP 36171; *14*, lateral view of posterior ear showing striated external ligament attachment area, ×2, *15*, lateral view, *16*, close-up of rubber cast of hinge line showing anterior and posterior ligament grooves, lateral and cardinal teeth, ×2, UMMP 36170.
*17,18—Pterinopecten insons* Hall, lateral views of two left valves, ×2, hypotypes UMMP 36169 and USNM 549501, respectively.
*19—Procrucibulum ?* sp., dorsal view, ×2, GSC 14751.
*20—Portlockiella ?* sp., lateral view showing lirae on body whorl, UMMP 36266.
*21,22—"Bellerophon"* sp., apertural and lateral views, UMMP 36225.
*23,24—Straparolus minutilineatus*, n. sp., *23*, close-up of growth lines, ×5, *24*, lateral view of of rubber cast, holotype, USNM 549504.
*25—Straparolus* sp., lateral view of very small specimen showing shell outline and growth lines, ×2, UMMP 36222.
*26—"Pleurotomaria"* sp., oblique dorsal view of low spired steinkern, UMMP 36224.
*27—Elasmonema* sp., oblique view of rubber cast showing fine growth lines, ×3, UMMP 36223.
*28—Elasmonema bellatulum* (Hall), lateral view of rubber cast, hypotype, UMMP 36220.
*29—Murchisonia* sp., GSC 14749.
*30—Murchisonia* (*Hormotomina*) *linsleyi*, n. sp., lateral view of rubber cast showing tricarinate seleni-zone and growth lines, ×2, USNM 549503.

## Explanation of Plate 13

(All figures ×1 unless otherwise indicated)

Figs. *1—Platyceras* sp. cf. *P. ammon* Hall, UMMP 36257.
*2—Platyceras* sp. cf. *P. erectum* (Hall), GSC 14750.
*3–5—Platyceras carinatum* Hall, exterior views showing sharp anterior keel and longitudinal growth lines, hypotype, USNM 549505.
*6–8—Mourlonia confertinemilata*, n. sp., *6*, exterior of large specimen, paratype, USNM 549502; *7*, close-up of rubber cast showing the nature of the selenizone, lirae, and growth lines, ×2, *8*, rubber mold, holotype, UMMP 36213.
*9–10—Platyceras dumosum rarispinum* Hall, *9*, lateral view, *10*, dorsal view, hypotype, UMMP 36255.
*11,12—Platyceras* sp., lateral and dorsal views showing coarse longitudinal plications, UMMP 36258.
*13,14—Brevicoceras* sp. cf. *B. conicum* Flower, *13*, dorsal view, *14*, lateral view, UMMP 36229.
*15,16—Acleistoceras* sp. cf. *A. hyatti* (Whitfield), *15*, ventral view, *16*, lateral view, UMMP 36226.
*17,18—Goldringia* sp. cf. *G. citum* (Hall), *17*, ventrolateral view showing the crenulated frills, growth lines, and hyponomic sinus, ×2, GSC 14752; *18*, lateral view of large specimen, UMMP 36227.
*19—Goldringia* sp. cf. *G. ammon* (Billings), ventral view of rubber cast showing frills and hyponomic sinus, UMMP 26668.
*20,21—Exocyrtoceras ?* sp., ventral and lateral views, UMMP 36231.
*22–27—Exocyrtoceras minutum* Flower, *22,23*, ventral and lateral views of a specimen in two parts showing body chamber and part of phragmocone, hypotype, UMMP 36271; *24*, ventral view, *25*, adapical view showing location of siphuncle, hypotype, UMMP 36230;

*26*, ventral view of living chamber showing muscle attachment impressions, ×2, hypotype, UMMP 36267; *27*, lateral view of living chamber showing transverse constriction, hypotype, UMMP 36269.

*28*—*Dawsonoceras ?* sp. cf. *D. americanum* (Foord), lateral exterior view of annulated phragmocone, UMMP 36228.

*29*—*Spyroceras ?* sp. cf. *S. thoas* (Hall), rubber cast of annulated phragmocone showing longitudinal striations, UMMP 36226.

EXPLANATION OF PLATE 14

(All figures ×1 unless otherwise indicated)

FIGS. *1,2*—*Mystrocephala stummi*, n. sp., *1*, dorsal view of incomplete cephalon, ×2, *2*, same showing detail of ornamentation, ×10, holotype, GSC 14753.

*3*—*Mystrocephala* sp., dorsal view of incomplete cephalon, ×2, GSC 14755.

*4,5,20*—*Dechenella* (*Basidechenella*) *formosensis*, n. sp., *4*, dorsal view of incomplete cephalon showing typical sigmoid facial sutures, ×2, holotype, UMMP 36244; *5*, dorsal view of somewhat smaller cephalon, ×2, paratype, GSC 14756; *20*, dorsal view of pygidium showing nodose crest on axial lobe, ×2, paratype, UMMP 36149.

*6,7*—*Proetus* (*Crassiproetus*) *crassimarginatus brevispinosus*, n. subsp., *6*, dorsal view, *7*, lateral view showing short genal spine, holotype, UMMP 36154.

*8–12*—*Proetus* (*Crassiproetus*) *crassimarginatus* (Hall), *8*, dorsal view of cephalon, hypotype, UMMP 29538; *9*, dorsal view of small pygidium, ×2, hypotype, GSC 14757; *10*, lateral view of genal angle without genal spine, hypotype, UMMP 36150; *11*, dorsal view of pygidium showing shallow median furrows on the anterior pleural lobes, ×2, hypotype, UMMP 36153; *12*, dorsal view of pygidium, hypotype, UMMP 36151.

*13–17*—*Echinolichas parallelobatus*, n. sp., *13–15*, dorsal, lateral, and posterior views of a nearly complete cephalon, holotype, UMMP 36172; *16*, dorsal view of smaller, less complete cephalon with shallower longitudinal glabellar furrows, paratype, UMMP 36173; *17*, dorsal view of nearly complete pygidium showing almost parallel posterior axial furrows, paratype, UMMP 36148.

*18,19*—*Dechenella* (*Dechenella*) (?) *halli* Stumm, *18*, dorsal view of pygidium, *19*, posterior view of pygidium, ×2, hypotype, GSC 14758.

*21,22*—*Dawsonoceras ?* sp. cf. *D. americanum* (Foord), *21*, exterior view showing annulations, *22*, interior section showing orthochoanitic septal necks and connecting rings, UMMP 42254.

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*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36245–36247

Suborder RHYNCHONELLOIDAE
Superfamily RHYNCHONELLACEA
Family CAMAROTOECHIIDAE
Subfamily CAMAROTOECHIINAE
Genus CAMAROTOECHIA Hall & Clarke, 1894

*Type species.*—*Atrypa congregata* Conrad.

CAMAROTOECHIA TETHYS (Billings)
Pl. 9, figs. 1–12

*Rhynchonella ? tethys* Billings, 1860, p. 270, figs. 20–22.

*Rhynchonella* (*Stenoscisma*) *tethys* Hall, 1867, p. 335, pl. 54, figs. 1–8.

*Camarotoechia tethys* Hall & Clarke, 1894, p. 192, pl. 57, figs. 1,2.

*Remarks.*—This species is rather abundant in the Formosa reefs being represented by all sizes from immature small specimens to other quite large individuals resembling *C. sappho* (Hall) of the Hamilton group. The decision to include the entire group as *C. tethys* (Billings) is based upon the complete size gradation in the Formosa specimens from those somewhat smaller than the typical *C. tethys* to those slightly smaller than the typical *C. sappho*. Additional collecting and study may indicate that these two species do intergrade and are synonymous.

*Occurrence.*—Localities 6, 12, 15, 41, 53.

*Types.*—Hypotypes UMMP 36259–36361 and 36264; GSC 14731; USNM 549473.

CAMAROTOECHIA FORMOSENSIS, n. sp.
Pl. 9, figs. 17–23

*Description.*—Shell small for the genus, width slightly greater or equal to length, greatest width near middle; valves equally convex in lateral profile, curvature slight, greatest toward beaks, thickness less than half the width. Outline subtriangular, posterolateral and anterior margins straight, anterolateral margins evenly rounded. Lateral and anterior extremities thin and sharp in anterior profile. Beak of pedicle valve suberect, brachial beak slightly incurved;

beak angle about 90°. Fold and sinus low, wide, flat, and rather well defined. Interior unknown.

Radial ornamentation very prominent, consisting of numerous, evenly spaced and sharp crested costae. Costae 6 on fold, 5 in sinus, and 6 on flanks, persistent to beaks and not increasing in number anteriorly. Costae and troughs V-shaped, straight medially becoming gently curved laterally. Concentric ornamentation consisting of inconspicuous, lamellose filia.

*Remarks.*—This species is characterized by thin, evenly convex, small valves. Specimens are very rare in the reefs of the Formosa area.

*Occurrence.*—Locality 6.

*Types.*—Holotype UMMP 36262; paratype USNM 549474.

CAMAROTOECHIA LAMELLOSA, n. sp.
Pl. 9, figs. 24–29

*Description.*—Shell of medium size for the genus, shape somewhat variable, width greater than length, greatest width near middle. In lateral profile pedicle valve almost plane medially, sharply incurved anteriorly, beak suberect; brachial valve gibbous, considerably inflated anteriorly, beak incurved well over hinge line. Outline subtriangular, posterolateral margins straight, anterior margin nearly straight, and anterolateral borders evenly rounded. Lateral and anterior extremities of both valves flat in anterior profile. Beak angle 80°–100°. Fold and sinus prominent, moderately wide, and flat to gently rounded. Interior unknown.

Ornamentation moderately prominent, consisting of somewhat unequal, low, rounded costae and irregularly spaced, lamellose growth lines. Costae mostly wider than the intervening, shallow troughs, 4 to 6 on fold and sinus, 3 to 5 on flanks, generally not persistent to beaks, and occasionally increasing by bifurcation anteriorly. Concentric ornamentation consisting of numerous, inconspicuous, closely spaced filia, and a few rather prominent lamellae.

*Remarks.*—This species is characterized by the subdued radial ornamentation and the presence of a few conspicuous, lamellose growth lines. Specimens are quite rare in the Formosa reefs.

*Occurrence.*—Localities 4, 6, 12.

*Types.*—Holotype UMMP 36263 and paratype UMMP 36294; paratypes GSC 14732, 14733.

CAMAROTOECHIA AMBIGUA, n. sp.
Pl. 9, figs. 13–16

*Description.*—Shell small for the genus, slightly wider than long, greatest width near middle; valve about equally convex in lateral profile, curvature slight, greatest toward beaks, thickness less than one-third the width. Outline subtriangular, posterolateral margins straight, anterior margin nearly straight, and anterolateral margins evenly rounded. Lateral and anterior extremities thin and sharp in anterior profile. Beak of pedicle valve suberect, brachial beak slightly incurved, beak angle about 90°. Fold and sinus low, wide, rather flat, and poorly defined. Interior unknown.

Ornamentation subdued; costae low, rounded, rather irregularly elevated, of variable width and spacing, and not persistent to the beaks. Growth lines fairly conspicuous, lamellose, irregularly spaced becoming more numerous and more closely spaced toward the anterior margin. Costae increasing slightly in number by intercalation, the new costae appearing just anterior to the major growth lines.

*Remarks.*—This species is nearly identical with *C. formosensis*, n. sp., with regard to its general small size and overall shell shape. The conspicuous growth lines and low, rounded costae strongly resemble the ornamentation of *C. lamellosa*, n. sp. It is unfortunate that sufficient specimens of *C. formosensis*, *C. lamellosa*, and particularly of *C. ambigua* have not as yet been collected to be certain of the variability and diversity of these three species. However, on the basis of presently available material, each appears to be sufficiently distinct for description as a new species.

*Occurrence.*—Locality 53.

*Type.*—Holotype UMMP 36265.

Superfamily STENOSCISMATACEA
Family STENOSCISMATIDAE
Subfamily STENOSCISMATINAE
Genus STENOSCISMA Conrad, 1839

*Type species.*—*Terebratula schlotheimii* von Buch.

STENOSCISMA RHOMBOIDALIS Hall & Clarke
Pl. 9, figs. 45–47

*Camarophoria rhomboidalis* Hall & Clarke, 1894, pl. 62, figs. 25,26, *non* pl. 62, figs. 27–29; Hall, 1895, p. 363, pl. 9, fig. 37 *non* pl. 9, figs. 38–40.

*Remarks.*—This species is represented by three well preserved specimens collected from the Formosa reefs. All are somewhat smaller than the holotype but otherwise they are very similar in all essential features having three low, rounded costae on the fold, and 2 or 3 non-persistent costae on the anterolateral flanks.

*Occurrence.*—Localities 6, 43.

*Types.*—Lectotype (here designated) no. 1172, paratypes no. 1173, New York State Museum; hypotypes USNM 549475, 549476; GSC 14734.

STENOSCISMA HALLI, n. sp.
Pl. 9, figs. 48–51

*Camarophoria rhomboidalis* Hall & Clarke, 1894, pl. 62, figs. 27–29; Hall, 1895, p. 363, pl. 9, figs. 38–40.

*Description.*—Shells small for the genus, subtriangular in outline, with the width somewhat greater than the length; greatest width at about the middle. Posterolateral margins gently concave, anterolateral margins narrowly rounded, and anterior margin nearly straight. Beak angle about 90°. Fold and sulcus originating a short distance anterior to the middle.

Pedicle valve gently convex in lateral profile with greatest convexity in posterior half; anterior profile about equally convex. Sulcus shallow but sharply delimited. Tongue short and wide. Beak ridges not prominent; beak suberect.

Brachial valve gently convex in lateral profile; somewhat more convex in anterior profile. Fold low, sharply delimited, flat. Anterolateral slopes short but abrupt.

Radial ornamentation inconspicuous, scarcely perceptible beyond the anterior and anterolateral margins, consisting of low, rounded costae arranged with one in the sulcus, two on the fold, and two or three on each flank. Concentric ornamentation of varying prominence from numerous, almost imperceptible, closely spaced filia, to a few, more prominent, lamellose growth lines.

Septa of both valves not quite reaching middle.

*Remarks.*—This species is clearly distinct from *S. rhomboidalis* Hall & Clarke in having the width greater than the length and two, larger and more prominent costae on the fold.

Hall's original specimens for *S. rhomboidalis* were reported from the Corniferous limestone (Onondaga in modern usage) at Peru, Indiana. Cooper & Warthin (1941, p. 259–260) noted that the fauna of this locality correlates with the Four Mile Dam limestone of Michigan rather than the Onondaga and named the new formation in Indiana the Logansport limestone. Thus the presence of *S. rhomboidalis* and *S. halli* in the Formosa reef limestone marks the only known pre-Hamilton occurrence of the genus *Stenoscisma*.

*Occurrence.*—Locality 6.

*Type.*—Holotype USNM 549477.

STENOSCISMA sp.
Pl. 9, figs. 52,53

*Remarks.*—One specimen of a species similar to *S. illinoisensis* Cooper (1945, p. 484–485) was collected but it differs in having more subdued ornamentation and the lateral costae of the fold being less strongly elevated than the inner two costae. In addition the septa do not extend anterior to the middle, and the posterolateral margins are convex rather than concave. The Formosa reef specimen is too incomplete for description as a new species.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36274.

Suborder ATRYPOIDAE
Superfamily ATRYPACAE
Family ATRYPIDAE
Subfamily ATRYPINAE
Genus ATRYPA Dalman, 1828

*Type species.*—*Anomia reticularis* Linné.

ATRYPA sp. A
Pl. 9, figs. 35–40

*Remarks.*—A few small, multicostate, lens-shaped specimens of the genus *Atrypa* have been collected. Both valves are about equally convex and the posterolateral margins slope away from the beak to give a beak angle of about 110°. The fold and sulcus grade imperceptibly onto the flanks. A

rather wide frill is present on some specimens.

*Occurrence.*—Locality 6.

*Figured specimens.*—UMMP 36275; USNM 549478.

ATRYPA sp. B
Pl. 9, figs. 30–34

*Remarks.*—This species is somewhat more abundant than *A.* sp. A and is characterized by an inflated brachial valve and a well developed fold and sulcus with a rounded, short tongue. The shell outline and ornamentation are similar to *A. reticularis* Linné.

Both *Atrypa* sp. A and *A.* sp. B may be new species but since the genus is in such great need of restudy, they are not herein formally described since sufficient specimens are not presently available for a proper understanding of their morphological variation.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36276.

Suborder SPIRIFEROIDAE
Superfamily SPIRIFERACEA
Family SPIRIFERIDAE
Subfamily AMBOCOELIINAE
Genus METAPLASIA Hall & Clarke, 1894

*Type species.*—*Spirifer pyxidatus* Hall.

METAPLASIA UNIPLICATA, n. sp.
Pl. 9, figs. 41–44

*Description.*—Shells very small and only slightly wider than long. Beak angle about 90°. Interior unknown.

Brachial valve gently and evenly convex, subtrapezoidal, hinge line straight, long, anterior margin slightly concave, anterolateral margins straight and cardinal extremities smoothly rounded; greatest width located about one-third the length from the small beak to the anterior margin. Ornamentation consisting of a low, evenly rounded, slightly elevated mesial fold and one very low, wide radial plication on each flank separated from the fold by a rather prominent, wide, low, depression; growth lines numerous, inconspicuous. Radial ornamentation not persistent to beak and absent on cardinal extremities.

Pedicle valve extremely gibbous, greatest convexity at the beak; beak nearly erect, curving over part of the wide, rounded interarea. There is a prominent but not deeply depressed sinus bordered by one pair of sharply elevated, evenly rounded, narrow costae which are persistent to the beak. Beside each costa there is a shallow, non-persistent, wide depression grading imperceptably onto the smooth lateral flanks.

*Remarks.*—This species differs from all others in the genus *Metaplasia* by possessing just one pair of plications beside the mesial fold on the brachial valve.

*Occurrence.*—Locality 6.

*Types.*—Holotype USNM 549479 and paratypes USNM 549480, UMMP 36272, 36273.

Subfamily KOZLOWSKIELLINAE
Genus KOZLOWSKIELLINA Boucot, 1958

*Type species.*—*Kozlowskiella strawi* Boucot.

Subgenus KOZLOWSKIELLINA (MEGAKOZLOWSKIELLA) Boucot, 1957

*Type species.*—*Spirifer perlamellosus* Hall.

KOZLOWSKIELLINA (MEGAKOZLOWSKIELLA) SUBMERSA (Grabau)
Pl. 10, figs. 16–20

*Spirifer sulcata* mut. *submersa* Grabau, 1910, p. 136–137, pl. 18, figs. 4–6.
*Kozlowskiella* (*Megakozlowskiella*) *sulcatus* mut. *submersa* Boucot, 1957, p. 323.

*Remarks.*—The presence of numerous specimens of this species in the Formosa reefs lends considerable faunal support to the Detroit River age of the reefs. Grabau's types are from the Amherstburg dolomite near Amherstburg, Ontario and the species was unknown outside the type area of the Detroit River group prior to the discovery of these specimens in the Formosa reefs.

*Occurrence.*—Localities 6, 12, 43.

*Types.*—Hypotypes UMMP 36278–36284; USNM 549481, 54982; GSC 14735.

Subfamily ELYTHINAE
Genus ELYTHA Fredricks, 1924

*Type species.*—*Delthyris fimbriatus* Conrad.

ELYTHA FORMOSENSIS, n. sp.
Pl. 10, figs. 21–26

*Description.*—Shell of medium size for the genus; subpentagonal in outline, wider than long with the greatest width at about the middle. Hinge line straight and about half as long as the width of the shell. Anterior

margin slightly concave or straight, anterolateral margins straight or slightly convex, and posterolateral margins of brachial valve convex and evenly rounded and of pedicle valve straight. Interior unknown.

Brachial valve convex and inflated anteriorly in lateral profile; greatest curvature at the beak. Anterior profile subtriangular. Beak moderately incurved. Fold prominent, sharply elevated, non-costate, commencing at the beak and flaring anteriorly so that at the anterior margin it is nearly as wide as the hinge line; crest narrow, evenly rounded. Flanks with 2 to 4 pairs of low, evenly rounded, laterally curving costae with the inner pair more prominent than the others and arising almost at the beak. Posterolateral flanks non-costate.

Pedicle valve strongly convex in lateral profile and subtriangular in anterior profile. Beak erect; beak ridges moderately prominent, ventrally convex. Interarea concave, subtriangular, and with raised ridges at the border of the delthyrium. Sulcus wide, sharply depressed, non-costate, commencing at the beak and with a prominent, wide tongue which is almost V-shaped in cross section bending sharply into the brachial fold. Sulcus bordered by a pair of prominent, evenly rounded costae; 2 or 3 pairs of less prominent costae on the flanks. Posterolateral flanks non-costate.

Concentric ornamentation subdued, consisting of a few low growth lines and numerous, regularly spaced, lamellose fimbriate filia.

*Remarks.*—This species is characterized by its medium size and the relatively few, low, rounded costae on the flanks. The spine bases in all the Formosa specimens are very poorly preserved but apparently they are single (see Stainbrook, 1940, p. 414). Specimens are quite rare in the Formosa reef limestone.

*Occurrence.*—Localities 6, 41, 53.

*Types.*—Holotype USNM 549483; paratypes UMMP 36301, 36302; GSC 14736.

Subfamily SPIRIFERINAE
Genus FIMBRISPIRIFER Cooper, 1942

*Type species.*—*Spirifer venustus* Hall.

FIMBRISPIRIFER DIVARICATUS (Hall)
Pl. 10, figs. 1–7

*Spirifer divaricatus* Hall, 1857, p. 133.

*Spirifera divaricata* Hall, 1867, p. 213, pl. 32, figs. 1,9; Nettelroth, 1889, p. 113, pl. 12, figs. 5–11.

*Fimbrispirifer divaricatus* Cooper, 1944, p. 323, pl. 123, figs. 1,2.

*Redescription.*—Shells large, suboval in outline, with the length about two-thirds the width; width greatest at about the middle. Hinge line long, straight, with lateral margins extending beyond as rather evenly rounded wings. Anterior margin straight or slightly concave.

Brachial valve gently and evenly convex in lateral and anterior profile. Beak fairly prominent and suberect. Fold commencing near the beak, sharply elevated, evenly rounded, with 5 to 9 low, rounded, bifurcating costae on the flanks of the fold. There is generally a sharply depressed, narrow, mesial furrow on the fold near the beak which may widen and persist anteriorly or lose its identity anteriorly, in which case the crest of the fold bears a low, rounded ridge without any evidence of a mesial furrow. The flanks of the valve have 15 to 19 prominent, rounded, laterally curving costae, most of which are persistent nearly to the beak; however, a few costae near the fold may bifurcate anteriorly.

Pedicle valve gently convex in lateral profile with greatest curvature near the suberect beak. Anterior profile evenly rounded or with flanks only slightly convex. Sulcus commencing at the beak, prominent, evenly rounded, with 6 to 8 low, rounded costae, one or two of which may bifurcate anteriorly. Flanks of the valve having numerous costae similar to those on the flanks of the brachial valve. Interarea wide, concave, triangular; beak ridges fairly distinct. Interior with strong dental plates and a short myophragm.

Concentric ornamentation consisting of a few prominent to almost inconspicuous, low rounded, widely and irregularly spaced growth lines and numerous, closely spaced, lamellose filia with one row of minute, radially elongated spines along the anterior margin of each.

*Remarks.*—Although this species was described over 100 years ago it is still quite poorly understood since the original descriptions of both *F. divaricatus* and *F. venustus* were not accompanied by illustrations. A few years later Hall (1867, p. 213, pl. 32) considered these species as synony-

mous and illustrated them both for the first time under the same name. The specimen used for pl. 32, fig. 1 (probably a *F. divaricatus, sensu stricto*) is apparently lost.

The taxonomic significance of the medial depression on the fold is as yet uncertain. It is quite variable in the Formosa reef specimens but generally is poorly developed or absent. Examination of the specimens of *F. divaricatus, sensu stricto* from the Jeffersonville limestone in the collections of the U. S. National Museum indicates that the depression may be well developed (note also Cooper, 1944, pl. 123, figs. 1,2; Nettelroth, 1889, pl. 12, fig. 10). However, no taxonomic discrimination is made in this report on this feature of the fold since it is so variable among the numerous Formosa specimens.

*Occurrence.*—Localities 4, 6, 12, 41, 53.

*Types.*—Hypotypes UMMP 36285–36293.

FIMBRISPIRIFER TRICOSTATUS, n. sp.
Pl. 10, figs. 9–13

*Description.*—Shells of small to medium size for the genus, suboval in outline, with the length about two-thirds the width; width greatest at about the middle. Hinge line long, straight, with lateral margins extending beyond as rather evenly rounded wings. Anterior margin evenly curved or concave. Interior unknown.

Brachial valve gently and evenly convex in lateral and anterior profile. Beak suberect. Fold sharply elevated, unevenly rounded, generally with one prominent, flat crested costa commencing near the beak and then trifurcating unequally at about the middle into a pair of smaller, lower, round crested lateral costae making three rather distinct costae on the fold at the anterior margin. There may be a mesial furrow on the medial costa near the beak but if present is generally shallow, narrow, and not persistent anteriorly beyond the middle. The flanks of the valve have 7 to 9 prominent, rounded, laterally curving costae which are not persistent to the beak and generally do not bifurcate anteriorly.

Pedicle valve gently convex in lateral profile with greatest curvature near the nearly erect beak. Anterior profile evenly rounded or with flanks only slightly convex. Sulcus commencing at the beak, non-costate posteriorly but with 2 to 4 low, rounded costae arising by intercalation anteriorly. Flanks of the valve bearing costae similar to those on the flanks of the brachial valve. Interarea wide, concave, triangular; beak ridges fairly distinct.

Concentric ornamentation poorly preserved but apparently similar to *F. divaricatus* (Hall).

*Remarks.*—This species is so very similar to *F. divaricatus* (Hall) and *F. grieri* (Hall) that there is a strong possibility that all three species are synonymous. However, until such time as sufficient specimens of each are available, they are here considered to be distinguished as follows:

1. *F. divaricatus* (Hall *sensu stricto*) is larger and with more costae on the fold, sulcus, and flanks than either of the other two. Whether or not the costation is an effect of size so that this species merely represents mature individuals is uncertain.

2. *F. grieri* (Hall) is smaller than *F. divaricatus*, of about the same size as *F. tricostatus* but with more than 3 or 4 costae on the fold and sulcus.

3. *F. tricostatus*, n. sp. is characterized by its small to medium size, the relatively fewer costae, and the prominent, flat crested medial costa on the fold. However, these features of the costae may not be as diagnostic as they now appear since one specimen (UMMP 36296) has two costae on one flank of the fold, only one costa on the other flank, and the medial costa has a persistent shallow mesial furrow so that at the anterior margin the fold bears 5 costae.

*Occurrence.*—Localities 6, 12.

*Types.*—Holotype UMMP 36295 and paratypes UMMP 36296–36299, GSC 14737, 14738, USNM 549484, 549485.

"SPIRIFER" sp. A
Pl. 10, fig. 8

*Remarks.*—This species, known only from four pedicle valves, resembles *Spirifer duodenaria* Hall except that the greatest width is not at the hinge line. A study of additional specimens would probably indicate that this is a new species.

*Occurrence.*—Localities 6, 15, 53.

*Figured specimen.*—UMMP 36300.

"SPIRIFER" sp. B
Pl. 10, figs. 14,15

*Remarks.*—This spiriferid is known from one brachial valve and the attached sulcus

or tongue of the pedicle valve. The brachial fold is strongly elevated with two rounded costae separated by a prominent, mesial furrow which meets a low, rounded costa in the wide, flaring sulcus of the pedicle valve. This also is probably a new species.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36301.

Superfamily ROSTROSPIRACEA
Family MERISTELLIDAE
Subfamily MERISTELLINAE
Genus MERISTELLA Hall, 1860

*Type species.*—*Merista arcuata* Hall.

MERISTELLA NASUTA (Conrad)
Pl. 11, figs. 1–4

*Atrypa nasuta* Conrad, 1842, p. 265.
*Meristella nasuta* Hall, 1860, p. 93; 1867, p. 299, pl. 48, figs. 1–25.

*Remarks.*—This species is quite abundant in the Formosa reef limestone. The average size however, is slightly smaller than typical *M. nasuta* from the Onondaga limestone of New York.

*Occurrence.*—Localities 6, 12, 53.

*Types.*—Hypotypes UMMP 36303–36306; USNM 549486, 549487.

MERISTELLA BARRISI Hall
Pl. 11, figs. 5–10

*Meristella barrisi* Hall, 1860, p. 84; 1867, p. 304, pl. 49, figs. 9–12, possibly figs. 16-22, *non* figs. 13–15; Hall & Clarke, 1894, pl. 43, figs. 25,26, possibly pl. 44, figs. 27–30.

*Remarks.*—The specimens of this species in the Formosa reef limestone are similar to *M. barrisi* in all essentials. However, the growth lines are considerably more prominent than indicated in Hall's illustrations.

*Occurrence.*—Localities 6, 12, 53.

*Types.*—Hypotypes UMMP 36307–36309.

MERISTELLA FORMOSENSIS, n. sp.
Pl. 11, figs. 11–15

*Description.*—Shells medium to small for the genus, elongate-ovate in outline with greatest width slightly anterior to middle; sublenticular in lateral and anterior profiles. Anterior margin gently uniplicate. Beak angle about 75°.

Pedicle valve moderately and evenly convex. Beak suberect. Sulcus not depressed, indicated merely by a slightly elongated tongue-like extension of the anterior margin. Beak ridges inconspicuous, rounded. Dental plates apparently short, convex laterally, joining or nearly joining ventrally and resting upon the thickened muscle attachment area.

Brachial valve less convex than pedicle valve. Anterior margin broadly arched and elongated to form a barely perceptible fold. Cruralium large, V-shaped, and resting upon a low median septum which extends nearly to the middle.

*Remarks.*—This species is known from six nearly complete specimens from the Formosa reef limestone. It is quite similar to *M. barrisi* Hall but differs in having the greatest width nearer the middle, the beak angle more acute, and the growth ornamentation less prominent.

*Occurrence.*—Localities 6, 12, 43.

*Types.*—Holotype USNM 549488; paratypes UMMP 36310, GSC 14739–14741.

MERISTELLA ANGUSTISINUATA, n. sp.
Pl. 11, figs. 16–19

*Description.*—Shells small to medium for the genus, elongate-subpentagonal in outline with greatest width slightly anterior to midlength. Posterolateral, anterolateral and anterior margins straight or slightly convex. Beak angle about 60°. Anterior profile subcircular, thickness almost as great as width, lateral margins only slightly angulated; anterior margin sharply uniplicate. Valves non-costate.

Pedicle valve strongly and evenly convex in lateral profile. Sulcus inconspicuous; medial portion of the valve extending prominently forward as a smooth, tongue-like extension of the shell into the brachial fold. Beak ridges low, rounded; beak suberect. Dental plates apparently short, convex laterally, joining or nearly joining ventrally and resting upon the thickened muscle attachment area.

Brachial valve gently convex in lateral profile becoming flattened anteriorly; curvature greatest near beak. Fold commencing at midlength as a low, rounded plication increasing rapidly in prominence anteriorly so that at the anterior margin it is very strongly elevated, relatively narrow, and evenly rounded. Median septum narrow, extending anteriorly almost to the middle.

Growth lines fairly prominent, somewhat lamellose, rounded, irregularly spaced but

most conspicuous along anterolateral and anterior margins.

*Remarks.*—This species is known from four nearly complete specimens and is characterized by the short, narrow, sharply elevated fold and relatively acute beak angle. Hall (1867, pl. 49, figs. 13–15) illustrated a specimen as *M. barrisi* from the Hamilton group. This specimen is apparently similar to or perhaps conspecific with *M. anguistisinuata*. In the Formosa reefs, however, these two species are markedly distinct and cannot be considered as synonymous.

*Occurrence.*—Localities 43, 53.

*Types.*—Holotype GSC 14742; paratypes USNM 549489–549491.

MERISTELLA SUBROTUNDA, n. sp.
Pl. 11, figs. 30–34

*Description.*—Shells small for the genus, elongate-ovate in outline with greatest width well ahead of the middle. Posterolateral margins slightly convex to nearly straight, anterolateral and anterior margins gently and evenly rounded. Anterior profile subcircular, thickness almost as great as width, lateral margins only slightly angulated; anterior margin gently uniplicate. Beak angle about 50°. Valves non-costate.

Pedicle valve strongly and evenly convex in lateral profile. Sulcus not depressed, indicated merely by a low, smooth rise in the anterior profile. Beak ridges low, rounded; beak suberect. Dental plates apparently short, convex laterally, joining or nearly joining ventrally and resting upon the thickened muscle attachment area.

Brachial valve moderately and evenly convex in lateral profile. Fold inconspicuous, indicated merely by a low, smooth rise in the anterior profile. Median septum narrow, considerably shorter than half the valve length.

Growth lines fairly prominent, somewhat lamellose, rounded, and irregularly spaced.

*Remarks.*—This species is represented by five well preserved specimens from the Formosa reef limestone. It resembles *M. angustisinuata*, n. sp. in general form but lacks the prominent, narrow fold.

*Occurrence.*—Localities 4, 6, 47, 53.

*Types.*—Holotype UMMP 36311; paratypes UMMP 36312, GSC 14743.

Genus CAMAROSPIRA Hall & Clarke, 1894

*Type species.*—*Camarophoria eucharis* Hall.

CAMAROSPIRA sp.
Pl. 11, figs. 35,36

*Remarks.*—This genus is represented by one specimen of a species which is larger, wider, and with a less acute beak angle than the type species. The ventral and dorsal median septa are narrow and long, apparently extending to about the middle. A study of additional specimens will almost certainly indicate this to be a new species.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36313.

Family ATHYRIDAE
Subfamily ATHYRINAE
Genus ATHYRIS McCoy, 1844

*Type species.*—*Terebratula concentrica* von Buch.

ATHYRIS CORA Hall
Pl. 10, fig. 27; Pl. 11, figs. 37–41

*Athyris cora* Hall, 1860, p. 94; 1867, p. 291, pl. 47, figs. 1–7; Hall & Clarke, 1894, p. 90, pl. 45, figs. 6–10.

*Remarks.*—This species is represented by seven specimens from the Formosa reef limestone. This is the oldest reported occurrence of the species which is typically of lower Hamilton age.

*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36314–36317, USNM 549492.

ATHYRIS MINUTA, n. sp.
Pl. 11, figs. 42–44

*Description.*—Shell very small for the genus, slightly longer than wide, greatest width at about the middle. Outline subpentagonal; posterolateral margins slightly concave, anterolateral margins slightly convex, and anterior margin straight. Beak suberect, foramen large, circular; beak ridges inconspicuous, low, rounded. Beak angle about 90°. Valves both strongly and about equally convex in anterior profile, anterior margin uniplicate; sulcus and fold apparent only by gentle undulation of anterior margin.

Pedicle valve moderately convex in lateral profile; greatest curvature at beak. Interior unknown.

Brachial valve slightly less convex than

pedicle valve in lateral profile; curvature even. Median septum inconspicuous, extending to about the middle.

Ornamentation consisting only of well developed, numerous, somewhat regularly spaced, low, rounded, lamellose growth lines.

*Occurrence.*—Locality 6.

*Types.*—Holotype USNM 549500; paratype USNM 549508.

Suborder TEREBRATULOIDEA
Superfamily TEREBRATULACEA
Family DIELASMATIDAE
Subfamily CRANAENINAE
Genus CRANAENA Hall & Clarke, 1894

*Type species.*—*Terebratula romingeri* Hall.

CRANAENA ROMINGERI (Hall)
Pl. 11, figs. 20–24

*Terebratula romingeri* Hall, 1863, p. 48; 1867, p. 389, pl. 60, figs. 17–25.
*Cranaena romingeri* Hall & Clarke, 1894, p. 297, pl. 80, figs. 13–19.

*Remarks.*—This species is here identified on the basis of the suberect curvature of the beak, the permesothyrid position of the foramen relative to the beak ridges, and the external form. Serial sectioning of the Formosa reef specimens fails to reveal anything concerning the nature of the loop. Fifteen specimens have been collected from the Formosa reef limestone.

*Occurrence.*—Localities 4, 6, 43, 53.

*Types.*—Hypotypes UMMP 36318, 36319; USNM 549493–549497; GSC 14744–14746.

Genus CRYPTONELLA Hall, 1861

*Type species.*—*Terebratula rectirostra* Hall.

CRYPTONELLA LENS (Hall)
Pl. 11, figs. 25–29

*Terebratula lens* Hall, 1860, p. 89; 1867, p. 386, pl. 60, figs. 1–4.
*Cryptonella lens* Hall & Whitfield, 1872, p. 199.
*Cryptonella ? lens* Cloud, 1942, p. 129.

*Remarks.*—This species is here identified on the basis of the nearly straight curvature of the beak, the mesothyrid position of the foramen relative to the beak ridges, and the external form. Serial sectioning of the Formosa reef specimens fails to reveal anything concerning the nature of the loop. Nine specimens have been collected, some of which have a slight indication of a low fold and shallow sulcus.

*Occurrence.*—Localities 4, 6, 18, 53.

*Types.*—Hypotypes UMMP 36320, 36321; USNM 549498, 549499, GSC 14747.

Phylum MOLLUSCA
Class PELECYPODA
Order TAXODONTA
Suborder CTENODONTA
Family SOLENOPSIDAE
Genus SANGUINOLITES McCoy, 1844

"SANGUINOLITES" sp.
Pl. 12, fig. 10

*Remarks.*—A single left valve is illustrated showing the exterior outline and ornamentation. It is tentatively referred to this genus until the nature of the teeth can be known when additional specimens have been collected.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36168.

Order DYSODONTA ?
Family MYTILIDAE ?
Genus A sp. A
Pl. 12, figs. 11–16

*Description.*—Shell very large, longitudinal outline convex, curvature greatest toward beak, ventral margin smoothly rounded. Beak prominent, slightly incurved over the hinge line, sharply pointed, and with little or no anterolateral curvature. Hinge line moderately long, straight, produced posteriorly into a prominent, rounded ear and anteriorly into a less prominent ear extending only slightly ahead of the beak. Ligament external, divided by the cardinal teeth into posterior and anterolateral portions. Posteriorly the ligament attachment area consists of a wide, roughened plate with numerous, shallow striations elongated parallel to the hinge line. Anterolaterally the ligament attachment grooves are deeper and more prominent, curving in a concave arc from the anterior ear a short distance along the lateral margin of the valve where they are partially hidden beneath the concave anterolateral portion of the beak.

The teeth consist of three well developed cardinals located in the anterior ear and one low, straight lateral tooth elongated parallel to the hinge line and located along the inner margin of the ligament attachment area. The outer pair of cardinal teeth join ante-

riorly and diverge posterolaterally while the central cardinal tooth is not joined to either of the other two and merely occupies part of the space between them.

The ornamentation consists of a few irregularly spaced growth lines, some of which are more pronounced toward the ventral margin. Radial ornamentation absent or poorly developed. Muscle scars unknown.

*Remarks.*—This is probably a new genus and new species. However, since both specimens from the Formosa reefs are so incomplete, a diagnosis of the generic and trivial characters is impossible. More complete taxonomic understanding therefore must await additional collecting in this area.

*Occurrence.*—Localities 6, 53.

*Figured specimens.*—UMMP 36170, a steinkern of a mature right valve and 36171, a steinkern of both immature valves.

Family PTERIIDAE
Genus PTERINOPECTEN Hall, 1884

*Type species.*—*P. undosus* Hall.

PTERINOPECTEN INSONS Hall
Pl. 12, figs. 17,18

*Pterinopecten insons* Hall, 1884, p. 59–60.

*Remarks.*—This species is not abundant in the Formosa reef limestone but most of the specimens collected to date are rather well preserved; two specimens are herein illustrated, both left valves showing the long, straight hinge line and numerous radial ribs.

*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36169, USNM 549501.

Order HETERODONTA
Family CONOCARDIIDAE
Genus CONOCARDIUM Bronn, 1835

*Type species.*—*C. hibernicum* Sowerby.

CONOCARDIUM CUNEUS (Conrad)
Pl. 12, figs. 1–3,9

*Pleurorhynchus cuneus* Conrad, 1840, p. 206.
*Conocardium cuneus* Hall, 1885, p. 409.

*Remarks.*—This is the most abundant species of the genus *Conocardium* in the Formosa reef limestone. However, the specimens collected to date are all very poorly preserved and incomplete; the greatest numbers are poor casts of the anterior sloping end and the hood. The "tubular opening" at the junction of the valves in the hood as described by Hall (1885, p. 409) is present in several specimens. LaRocque (1950, p. 320–321) did not report this species as occurring in the Detroit River group in southeastern Michigan.

*Occurrence.*—Localities 6, 18.

*Types.*—Hypotypes UMMP 36164-36166.

CONOCARDIUM OHIOENSE Meek
Pl. 12, figs. 4–6

*Conocardium ohioense* Meek, 1871, p. 65–66.

*Remarks.*—Several very poorly preserved specimens of this species have been collected from the Formosa reef limestone. They all differ from *C. sibleyense* LaRocque in being less constricted anteriorly and somewhat smaller.

*Occurrence.*—Localities 6, 12.

*Types.*—Hypotypes UMMP 36161-36163, GSC 14748.

CONOCARDIUM sp.
Pl. 12, figs. 7,8

*Remarks.*—A single very small, incomplete specimen of a species of the genus *Conocardium* was collected at the type locality of the Formosa reef limestone. It is probably from an immature individual and is too poorly developed for an accurate specific identification although the state of preservation is considerably better than most pelecypod specimens from the Formosa area.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36167.

Class GASTROPODA
Subclass PROSOBRANCHIA
Order ARCHEOGASTROPODA
Superfamily BELLEROPHONTACEA
Family BELLEROPHONTIDAE
Genus BELLEROPHON de Montfort, 1808

*Type species.*—*B. vasulites* de Montfort.

"BELLEROPHON" sp.
Pl. 12, figs. 21,22

*Remarks.*—Only very small planispirally coiled "bellerophontid" steinkern with a very low, indistinct ridge in the plane of symmetry of the outer whorl was collected. Since none of the features of ornamentation are preserved, no certain identification is possible.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36225.

Superfamily PLEUROTOMARIACEA
Family PLEUROTOMARIIDAE
Subfamily PLEUROTOMARIINAE
Genus PLEUROTOMARIA de France

*Type species.*—*P. similis* Sowerby.

"PLEUROTOMARIA" sp.
Pl. 12, fig. 26

*Remarks.*—One low spired "pleurotomarian" steinkern without any indication of ornamentation was collected. No identification is possible.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36224.

Family PORTLOCKIELLIDAE
Genus PORTLOCKIELLA Knight, 1945

*Type species.*—*P. kentuckyensis* Knight.

PORTLOCKIELLA ? sp.
Pl. 12, fig. 20

*Remarks.*—Several incomplete pleurotomarian steinkerns have been collected having relatively high spires and at least six revolving lirae on the body whorl. The most prominent lira occurs at the angular junction of the base and the outer whorl face.

*Occurrence.*—Localities 6, 12.

*Figured specimen.*—UMMP 36266.

Subfamily PTYCHOMPHALININAE !
Genus MOURLONIA de Koninck, 1883

*Type species.*—*Helix carinatus* Sowerby.

MOURLONIA CONFERTINEMILATA, n. sp.
Pl. 13, figs. 6–8

*Description.*—Shell medium to large, turbiniform, with shallow sinus in outer lip giving rise to a selenizone. Whorl profile gently arched and sloping outward above the periphery, sharply carinate at the periphery, and gently convex and sloping sharply inward toward the umbilicus below. Umbilicus wide and flaring broadly onto the base; present only in the last whorl. Nuclear whorls very high spired and apparently without ornamentation but with a prominent raised selenizone; on the succeeding whorls the sutures are prominent, deeply impressed, and slightly canaliculate, the selenizone strongly protruding, flat to slightly convex, and not covered by any portion of the later whorls. Outer lip oblique from the upper suture backward above the selenizone and slightly convex forward below the selenizone, then becoming rounded and slightly oblique backward toward the umbilicus.

Ornamentation in the adult whorls consisting of 16 to 18 prominently raised revolving lirae between the sutures and selenizone both above and below the periphery, and numerous, closely spaced, less prominent growth lines which together give the surface an evenly reticulate pattern. There is some indication that in the neanic whorls the growth lines are more prominent than the revolving lirae and that the latter disappear before the growth lines toward the nuclear whorls. Four to five revolving lirae present on the raised, flattened area of the selenizone with a slight indication that the outer pair may be somewhat more prominent than those in between.

*Remarks.*—This species is characterized by numerous, prominent revolving lirae and the sharply raised selenizone in the adult whorls. The specimens from the Formosa reefs are numerous but all are incomplete, consisting for the most part of portions of one or two whorls; in none is the aperture preserved.

*Occurrence.*—Localities 4, 6, 12, 53.

*Types.*—Holotype UMMP 36213; paratypes UMMP 36214–36218, USNM 549502.

Family MURCHISONIIDAE
Subfamily MURCHISONIINAE
Genus MURCHISONIA d'Archiac & de Verneuil, 1841

*Type species.*—*Muricites turbinatus* Schlotheim.

Subgenus MURCHISONIA (HORMOTOMINA) Grabau & Shimer, 1909

*Type species.*—*Murchisonia maia* Hall.

MURCHISONIA (HORMOTOMINA) LINSLEYI, n. sp.
Pl. 12, fig. 30

*Description.*—Shell moderately large, very high spired, many whorled; whorl profile gently and evenly rounded except for a slightly raised selenizone located just below mid-whorl. Sutures deep, shoulder lacking. Aperture unknown; margin of outer lip (reconstructed from growth lines) from the upper suture to the selenizone with strong backward obliquity and very slight forward convexity. Growth lines very inconspicuous,

unknown on the base, apparently low, rounded, not closely spaced, fasciculate, or costate. Selenizone containing three unequally elevated, prominent costae, becoming progressively less conspicuous toward the base; the median costa about equally spaced between the outer two. Shell thin.

*Remarks.*—This species most closely resembles *M.* (*Hormotomina*) *maia* Hall but differs in the lower position of the selenizone on the whorl and the absence of a shoulder, costate growth lines, and a shallow groove below the upper suture. In addition *M.* (*Hormotomina*) *linsleyi* is less than half the size of the specimens of *M.* (*Hormotomina*) *maia* illustrated by Knight (1941, pl. 45, fig. 5).

*Occurrence.*—Locality 6.

*Type.*—Holotype, a partially exfoliated external mold, USNM 549503.

MURCHISONIA sp.
Pl. 12, fig. 29

*Remarks.*—Several unornamented, high spired forms have been collected. They range in size from about 5 to 25 mm. in length from base to tip of spire. None can be properly identified.

*Occurrence.*—Localities 4, 6, 47.

*Figured specimen.*—GSC 14749.

Superfamily EUOMPHALACEA
Family EUOMPHALIDAE
Subfamily EUOMPHALINAE
Genus STRAPAROLUS de Montfort, 1810

*Type species.*—*S. dionysii* de Montfort.

STRAPAROLUS MINUTILINEATUS, n. sp.
Pl. 12, figs. 23,24

*Description.*—Shell moderately large, discoidal, with rounded whorls and a very small shallow umbilicus. Whorl profile evenly but sharply arched and without shoulders or any sort of revolving ornamentation or nodes. Sutures moderately deep becoming quite indistinct toward the nucleus. Aperture apparently almost circular in outline; outer lip bending obliquely backward in an even, gently convex arc toward the periphery.

Ornamentation consisting only of numerous, closely spaced (about 10 in 2 mm.), rounded growth lines separated by rounded interspaces of equal width showing no tendency toward grouping into fascicles.

*Remarks.*—This species is characterized by having very fine and closely spaced growth lines, no revolving ornamentation, and a flatly discoidal shell with a small umbilicus.

*Occurrence.*—Locality 6.

*Types.*—Holotype, an exterior mold, USNM 549504.

STRAPAROLUS sp.
Pl. 12, fig. 25

*Remarks.*—A single incomplete internal mold of a small species of this genus was collected. No specific identification is possible since the ornamentation is very poorly preserved.

*Occurrence.*—Locality 53.

*Figured specimen.*—UMMP 36222.

Superfamily TROCHONEMATACEA
Family TROCHONEMATIDAE
Subfamily HOLOPEINAE
Genus ELASMONEMA Fisher, 1885

*Type species.*—*Loxonema bellatula* Hall.

ELASMONEMA BELLATULUM (Hall)
Pl. 12, fig. 28

*Loxonema bellatula* Hall, 1861, p. 104.
*Callonema bellatula* Hall, 1879, p. 50–51.
*Elasmonema bellatulum* Knight, 1941, p. 110.

*Remarks.*—Several specimens, all incomplete, have been collected from the Formosa reef limestone and are here identified primarily on the basis of shell shape and the characteristic evenly spaced growth lines. The whorl profile is moderately arched and without shoulders; the sutures markedly depressed, non-ornamented, and non-canaliculate.

*Occurrence.*—Localities 6, 12.

*Types.*—Hypotypes UMMP 36219–36221.

ELASMONEMA sp.
Pl. 12, fig. 27

*Description.*—Size and shape of complete shell and nature of aperture and base unknown. Whorl profile moderately arched between sutures and without shoulders or any sort of revolving ornamentation or nodes. Sutures moderately deep and non-canaliculate, continuing upward to a small, unornamented nucleus. Outer lip arched obliquely backward from the upper suture.

Ornamentation consisting only of numerous, extremely fine and closely spaced (23

in 2 mm.), rounded growth lines separated by rounded interspaces of nearly equal width showing no tendency toward grouping into fascicles.

*Remarks.*—This specimen apparently resembles *Elasmonema elegans* (Hall). However, the sutures are deeper, the whorls are more highly arched and increase in size more uniformly than is indicated by Hall's drawings (1859, pl. 55, figs. 1b–d) of *E. elegans*. The Formosa specimen is too incomplete for description as a new species.

*Occurrence.*—Locality 47.

*Figured specimen.*—UMMP 36223.

Family PLAYTCERATIDAE
Genus PLATYCERAS Conrad, 1840

*Type species.*—*Pileopsis vetusta* Sowerby.

PLATYCERAS sp. cf. P. ERECTUM (Hall)
Pl. 13, fig. 2

*Acroculia erecta* Hall, 1843, p. 172,174.
*Platyceras erectum* Hall, 1861, p. 4; 1879, p. 5, pl. 2, figs. 4–11.

*Remarks.*—Several specimens collected from the Formosa reefs are markedly erect in the mature portion but the nuclear whorls are not preserved so certain specific identification is not possible.

*Occurrence.*—Localities 6, 43.

*Figured specimen.*—GSC 14750.

PLATYCERAS CARINATUM Hall
Pl. 13, figs. 3–5

*Platyceras carinatum* Hall, 1861, p. 5; 1879, p. 5–6, pl. 2, figs. 12–29.

*Remarks.*—Numerous specimens of this species have been collected in the Formosa area, all characterized by a sharp anterior keel bearing longitudinal plications and closely spaced growth lines. The plications are of somewhat darker color than the depressed areas between, which may be some indication of original color banding.

*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36254, USNM 549505.

PLATYCERAS DUMOSUM RARISPINUM Hall
Pl. 13, figs. 9,10

*Platyceras dumosum* var. *rarispinum* Hall, 1861, p. 10; 1879, p. 16–17, pl. 5, figs. 5–7,10.

*Remarks.*—Specimens of this subspecies in the Formosa reefs are typical of those described by Hall. The spine bases are not numerous but are large and prominently elevated.

*Occurrence.*—Locality 6.

*Types.*—Hypotypes UMMP 36255, 36256.

PLATYCERAS sp. cf. P. AMMON Hall
Pl. 13, fig. 1

*Platyceras ammon* Hall, 1861, p. 9; 1879, p. 20–21, pl. 8, figs. 7–10.

*Remarks.*—A few large specimens have been collected and are here compared with *P. ammon* Hall by virtue of size alone. They are mostly exfoliated and without the nuclear whorls.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36257.

PLATYCERAS sp.
Pl. 13, figs. 11,12

*Remarks.*—Two specimens from the Formosa reefs are unlike any described species. They are characterized by a few low, rounded antero- and dorsolateral longitudinal plications giving the exterior of the shell a series of closely spaced, undulating growth lines. The nuclear whorls are poorly preserved but apparently rather tightly coiled. The aperture is not compressed as in *P. carinatum* Hall but instead quite circular and flaring. Additional collecting may indicate that this is a new species; however, until such time, it is better left undescribed.

*Occurrence.*—Locality 6.

*Figured specimen.*—UMMP 36258.

Family CLISOSPIRIDAE ?
Genus PROCRUCIBULUM Perner, 1911

*Type species.*—*Calyptraea simplex* Perner.

PROCRUCIBULUM ? sp.
Pl. 12, fig. 19

*Remarks.*—One small steinkern of a patelliform gastropod which is questionably referred to this genus was collected by E. W. Best. There is a rounded, slightly raised brim around the edge of the entire shell, otherwise the specimen is unornamented. The apex is nearly in the center and apparently untwisted.

*Occurrence.*—Locality 6.

*Figured specimen.*—GSC 14751.

Class CEPHALOPODA
Subclass NAUTILOIDEA
Order MICHELINOCERATIDA
Family PSEUDORTHOCERATIDAE
Genus SPYROCERAS Hyatt, 1883

*Type species.*—*Orthoceras crotalum* Hall.

SPYROCERAS ? sp. cf. S. THOAS (Hall)
Pl. 13, fig. 29

*Orthoceras thoas* Hall, 1861, p. 47; 1879, p. 261–263.
*Spyroceras thoas* Grabau & Shimer, 1910, p. 64.

*Remarks.*—A single external mold of a portion of a regularly annulated and vertically striated phragmocone is referred to this species on the basis of ornamentation. The position of the siphuncle is unknown so the genus designation is uncertain; the annuli are somewhat more closely spaced than is typical of *S. thoas*.

*Occurrence.*—Locality 12.

*Figured specimen.*—UMMP 36226.

Genus DAWSONOCERAS Hyatt, 1883

*Type species.*—*Dawsonoceras hyatti* Foerste.

*Remarks.*—The type species is of Niagaran age and Flower (1945, p. 683) considers the genus to be restricted to the Silurian. However, until the relationships of the species indicated below have been studied in more detail and assigned to another genus, they are herein tentatively referred to the genus *Dawsonoceras*.

DAWSONOCERAS ? sp. cf. D. AMERICANUM (Foord)
Pl. 13, fig. 28; Pl. 14, figs. 21,22

*Orthoceras undulatum* (partim) Hall, 1852, p. 293–294, pl. 64, fig. 1a.
*Orthoceras annulatum americanum* (partim) Foord, 1888, p. 56–57.
*Dawsonoceras annulatum americanum* Grabau & Sherzer, 1910, p. 196–197; Stauffer, 1915, p. 278,284.
*Dawsonoceras americanum* Foerste, 1928, p. 34–36,279; Kindle and Miller, 1939, p. 56.

*Remarks.*—Several specimens of various sizes from about 4 to 24 mm. in diameter and up to 85 mm. long appear to belong to this species. However, all are steinkerns, so the fine, wrinkled growth lines between the annulations characteristic of *Dawsonoceras* are not present, making even the generic determination uncertain. The septal necks and connecting rings are orthochoanitic.

*Occurrence.*—Localities 6, 12.

*Figured specimens.*—UMMP 36228 and 42254.

Order ONCOCERATIDA
Family BREVICOCERATIDAE
Genus BREVICOCERAS Flower, 1938

*Type species.*—*B. casteri* Flower.

BREVICOCERAS sp. cf. B. CONICUM Flower
Pl. 13, figs. 13,14

*Brevicoceras conicum* Flower, 1938, p. 32.

*Remarks.*—One steinkern of the living chamber was collected and compares favorably with this species; however, the aperture is not preserved so no certain identification is possible. The specimen is slightly larger than the holotype.

*Occurrence.*—Locality 41.

*Figured specimen.*—UMMP 36229.

Genus EXOCYRTOCERAS Flower, 1938

*Type species.*—*E. exoticum* Flower.

EXOCYRTOCERAS MINUTUM Flower
Pl. 13, figs. 22–27

*Exocyrtoceras minutum* Flower, 1945, p. 718.

*Remarks.*—This is the most abundant of the cephalopod species in the Formosa reef limestone. One specimen (in two parts) consists of a nearly complete body chamber and the last 13 chambers of the phragmocone with the exception of the fifth which is missing. In none of the specimens is the aperture outline preserved.

The holotype has not been located in the collection at Ohio State University; however, the illustrations (Flower, 1945, pl. 1, figs. 1–3) show no evidence of muscle attachment impressions nor is such a feature noted in the description. These impressions are well developed on one specimen from the Formosa reefs and so this genus becomes the fourth of the Oncoceratida known to possess them. However, there are no large ventral retractor muscle impressions as described by Sweet (1959, p. 297–298) in *Onoceras*, *Beloitoceras*, and *Diestoceras*. Such muscles in *Exocyrtoceras* must have been located elsewhere than along the venter where there is no evidence of muscle attachment impressions of any sort. The lateral portions of the annular impression consist of numerous rhombohedral loculi

formed in the original shell by a slightly raised transverse row of nodes about 0.75 mm. wide and located about 0.5 mm. adorally from the base of the living chamber.

*Occurrence.*—Localities 6, 12.

*Types.*—Hypotypes UMMP 36230 and 36267–36271.

EXOCYRTOCERAS ? sp.
Pl. 13, figs. 20,21

*Remarks.*—Several steinkerns of the living chamber and in some cases with part of the phragmocone attached have been collected. All are considerably larger than *E. minutum* Flower and apparently orthoconic but in no case is the aperture preserved to make even the generic identification certain.

*Occurrence.*—Localities 4, 6.

*Figured specimen.*—UMMP 36231.

Family ACLEISTOCERATIDAE
Genus ACLEISTOCERAS Hyatt, 1883

*Type species.*—*Apioceras olla* Saemann.

ACLEISTOCERAS sp. cf. A. HYATTI (Whitfield)
Pl. 13, figs. 15,16

*Gomphoceras hyatti* Whitfield, 1882, p. 206–207.
*Acleistoceras hyatti* Foerste, 1927, p. 198.

*Remarks.*—One rather poorly preserved living chamber was collected from the Formosa reef limestone which compares quite favorably with this species. However, the specimen is about half as large as the holotype and the aperture is too incomplete for certain identification.

*Occurrence.*—Locality 12.

*Figured specimen.*—UMMP 36226.

Order RUTOCERATIDA
Family RUTOCERATIDAE
Genus GOLDRINGIA Flower, 1945

*Type species.*—*Gyroceras cyclops* Hall.

GOLDRINGIA sp. cf. G. CITUM (Hall)
Pl. 13, figs. 17,18

*Cyrtoceras citum* Hall, 1879, p. 372–373.
*Goldringia citum* Flower, 1945, p. 710.

*Remarks.*—This is probably one of the most abundant elements of the cephalopod fauna of the Formosa reefs; however, the specimens are all too poorly preserved to be definitely identified. The phragmocone is elliptical in cross section rather than round and there are no longitudinal ridges or nodes as indicated in Hall's original description, (1879, p. 372).

*Occurrence.*—Localities 6, 12.

*Figured specimens.*—UMMP 36227; GSC 14752.

GOLDRINGIA sp. cf. G. AMMON (Billings)
Pl. 13, fig. 19

*Cyrtoceras ammon* Billings, 1861, p. 361; Stauffer, 1915, p. 248.
*Rhyticeras ammon* Kindle & Miller, 1936, p. 111.

*Remarks.*—This species is perhaps represented by a very large but incomplete external mold showing the crenulate frills and hyponomic sinus. This tentative identification was made by Rousseau Flower (manuscript).

*Occurrence.*—Locality 53.

*Figured specimen.*—UMMP 26668.

Phylum ARTHROPODA
Class TRILOBITA
Order PTYCHOPARIIDA
Suborder ILLAENINA
Superfamily PROETACEA
Family PROETIDAE
Subfamily PROETINAE
Genus PROETUS Steininger, 1831

*Type species.*—*Calymene concinna* Dalman.

*Diagnosis.*—Glabella moderately to highly convex, subquadrate, longer than wide, with subparallel sides. Glabellar furrows lacking or indicated by faint shallow depressions, by color markings, or by impressions on internal molds. Free cheeks with a convex ocular platform and rounded genal angles or with short genal spines. Occipital lobes small. Occipital ring with or without axial node. Thorax of ten unornamented segments, axis and plurae of about equal width. Pygidium large or small, strongly or weakly segmented, with or without a distinct brim.

Subgenus PROETUS (CRASSIPROETUS) Stumm, 1953a
PROETUS (CRASSIPROETUS) CRASSIMARGINATUS (Hall)
Pl. 14, figs. 8–12

*Calymene crassimarginata* Hall, 1843, p. 172, fig. 5.
*Proetus crassimarginatus* Hall, 1859, p. 88.
*Phillipsia crassimarginata* Billings, 1861, p. 362.
*Proetus crassimarginatus* Hall, 1861, p. 72; 1862, p. 100; 1876, pl. 20, figs. 21–23, 26–31, *non* figs. 20,23,24; Hall & Clarke, 1888, p. 99–101, pl. 20,

figs. 21,22,26–31, pl. 22, figs. 20–23,26, possibly figs. 24,25, *non* pl. 20, figs. 6–8,20,23,24.

*Remarks.*—This is the most abundant trilobite species in the Formosa reef limestone occurring as isolated cephala and pygidia with occasional fragments of the thoracic segments. Specimen UMMP 36153 is unusual in that the anterior four segments of the right pleural lobe have shallow medial furrows extending from the axial lobe nearly to the brim. This feature was noted by Hall & Clarke (1888, p. 100).

*Occurrence.*—Localities 4, 6.

*Types.*—Refigured hypotype UMMP 29538 and hypotypes UMMP 36150–36153; GSC 14757.

PROETUS (CRASSIPROETUS) CRASSIMARGINATUS BREVISPINOSUS, n. subsp.
Pl. 14, figs. 6,7

*Description.*—Thorax and pygidium unknown. Cephalon semicircular with a relatively broad, flat brim, becoming low convex opposite the ocular platforms and having a longitudinally striated border. Glabella moderately convex, subquadrate, tapering very slightly anteriorly, with a rounded anterior margin. Glabellar furrows lacking on test. Occipital lobes subtrigonal, relatively large but low and inconspicuous. Occipital furrow relatively narrow, well impressed. Occipital rings smooth, relatively wide and low convex posterior to glabella, becoming thinner posterior to ocular platforms. Anterolateral pre-glabellar fields, subtrigonal, low convex. Palpebral lobes very small subtrigonal, with a rounded peripheral angle. Eyes relatively small, elongate, reniform, not as high as crest of glabella. Free cheeks with gently arched ocular platform, slightly convex brims, and short genal spines.

*Remarks.*—This subspecies has all the characteristics of *Proetus* (*Crassiproetus*) *crassimarginatus* except for possessing short genal spines, a feature sufficiently distinct to warrant a different name although the thorax and pygidium are unknown.

*Occurrence.*—Locality 6.

*Type.*—Holotype, an incomplete cephalon, UMMP 36154.

Subfamily DECHENELLINAE
Genus DECHENELLA Kayser, 1880

*Type species.*—*Phillipsia verneuili* Barrande.

Subgenus DECHENELLA (BASIDECHENELLA) Richter, 1912

*Type species.*—*D.* (*Basidechnella*) *kayseri* Richter, 1912, p. 278–281.

DECHENELLA (BASIDECHENELLA) FORMOSENSIS, n. sp.
Pl. 14, figs. 4,5,20

Possibly *Proetus verneuili* Hall & Clarke, 1888, pl. 20, figs. 18,19.

*Description.*—Thorax unknown. Glabella broad, moderately convex, markedly tapering anteriorly with a pronounced bend in the axial furrows about one-third the distance from the preglabellar furrow to the occipital furrow. Anterior pairs of glabellar furrows obsolete; posterior pair well developed, extending as a sigmoid curve from just behind the bend in the axial furrow to the occipital furrow, deeply incised in the central portion becoming shallow, flattened, and flaring toward anterior end and quite indistinct toward occipital furrow. Posterolateral glabellar lobes large, well defined, subtrigonal. Occipital lobes relatively small, well defined, elongate and suboval in outline. Posterior half of glabella tuberculate, fixed cheeks and occipital lobes smooth.

Pygidium evenly rounded posteriorly, relatively short and wide with a broad convex brim bearing large, rounded nodes. Axis highly convex, composed of about 10 segments, the anterior 5 with axial nodes. Pleurae with about 6 convex segments separated by broad, shallow furrows.

*Remarks.*—This species is quite similar to *Dechenella* (*Monodechenella*) *ovifrons* (Hall & Clarke) but may be distinguished from that species by having sigmoid posterior glabellar furrows and larger occipital lobes.

*Occurrence.*—Locality 6.

*Types.*—Holotype, an incomplete cephalon, UMMP 36244; paratypes UMMP 36149, GSC 14756, 14757.

Subgenus DECHENELLA (DECHENELLA) Kayser

DECHENELLA (DECHENELLA) (?) HALLI Stumm
Pl. 14, figs. 18,19

*Proetus verneuili* Hall, 1861, p. 73; 1862, p. 101; 1876, pl. 20, figs. 18,19, *non P. verneuili* Barrande, 1852, p. 119,129.

*Dechenella* (*Dechenella*) (?) *halli* Stumm, 1953b, p. 23.

*Remarks.*—Well preserved, isolated pygidia of this species are rather abundant in Formosa reef limestone. However, the axial lobe is somewhat wider than is normal for *Dechenella* (*Dechenella*).

*Occurrence.*—Localities 6, 43, 53.

*Types.*—Hypotypes GSC 14758, USNM 549506, 549507.

Family BRACHYMETOPIDAE
Genus MYSTROCEPHALA Whittington

*Type species.*—*Cordania pulchra* Cooper & Cloud, 1938.

MYSTROCEPHALA STUMMI, n. sp.
Pl. 14, figs. 1,2

*Description.*—Thorax and pygidium unknown. Cranidium semicircular with a broad brim, a highly convex glabella and slightly elevated fixed cheeks. Glabella about two-thirds as long as wide, widest near the middle, narrowly rounded at front. Frontal lobe subquadrate in outline, sloping evenly toward preglabellar field. Anterior glabellar furrow a shallow, oblique depression deepening anterolaterally and uniting with the shallow, narrow depression of the axial furrow. Second glabellar lobe elongate, well defined, and slightly swollen. Posterolateral glabellar furrows wide and deep. Occipital lobes moderately large, well defined and subtrigonal in outline. Fixed cheeks relatively broad with two low nodes located beside the second glabellar lobes; anterior node quite prominent, elongate nearly perpendicular to the long dimension of the second glabellar lobes. Posterior node low, indistinct, and nearly round in outline. Preglabellar furrow shallow; preglabellar field broad, concave, with anterior border upturned sharply.

Ornamentation extremely varied. Glabella and free cheeks marked by punctae of two distinct sizes; the larger are less numerous and commonly occur near posterior edge of the low glabellar tubercles. Preglabellar field ornamented by numerous small to large, prominent, pointed tubercles occurring in a band about half the width of preglabellar field adjacent to the glabella and numerous, rather conspicuous punctae largest around the tubercles becoming progressively smaller toward brim.

*Remarks.*—This new species strongly resembles *M. pulchra* Cooper and Cloud but is distinguished by lacking a prominent tubercle on the highest point of the occipital lobes and possessing two nodes on the fixed cheek beside the second glabellar lobe.

*Occurrence.*—Locality 6.

*Types.*—Holotype GSC 14753, and unfigured paratype GSC 14754, incomplete cephala.

MYSTROCEPHALA sp.
Pl. 14, fig. 3

*Remarks.*—Thorax and pygidium unknown. Cephalon incomplete and poorly preserved. Resembles *M. stummi* but glabellar lobes less prominent and with tubercles rather than nodes on fixed cheek beside second glabellar lobes. Occipital lobes without prominent tubercles.

*Occurrence.*—Locality 6.

*Figured specimen.*—GSC 14755.

Order LICHIDA
Family LICHIDAE
Subfamily LICHINAE
Genus ECHINOLICHAS Gürich, 1901

*Type species.*—*Lichas eriopis* Hall.

*Diagnosis.*—Echinolichadinae with anterior glabellar lobe inflated and covered with tiny tubercles Pygidium with three pairs of ribs ending in free points; axial lobe with two furrows which may be flaring or nearly or nearly parallel posteriorly.

ECHINOLICHAS PARALLELOBATUS, n. sp.
Pl. 14, figs. 13–17

*Description.*—Thorax unknown. Cephalon semicircular with a narrow but prominent, flat anterior border becoming wider toward the anterolateral portion and separated from the glabella by a sharply depressed furrow. Anterior glabellar lobe uniformly inflated and separated from the lateral glabellar lobes by prominent, parallel, longitudinal glabellar furrows nearly evenly depressed from the anterior glabellar furrow to the fourth glabellar furrow. Lateral glabellar lobes quadricomposite, suboval, and with slight depressions normal to the longitudinal glabellar furrows indicating the position of the third lateral glabellar furrows. Fourth glabellar furrows deeper than any others, and forming a shallow, nearly circular pit at the junction with the longitudinal glabellar furrows. Basal glabellar lobes very large, subrectangular, with a very shallow nearly bisecting the lobes into lateral

halves. Occipital segment prominent, highly arched, and widest at the axis becoming narrower due to crowding behind the large basal glabellar lobes toward the posterolateral border of the cephalon.

Entire cephalon ornamented by abundant, irregularly scattered tubercles, the largest of which occur on the basal glabellar lobes.

Pygidium nearly semicircular with axial lobe almost as wide as each pleural lobe. Three pairs of rather long ribs ending in sharp points which extend in a posterolateral direction from borders of pleural lobes. Pygidium unsegmented except for possibly one segment at anterior end; three prominent, rounded ribs on each pleural lobe. Axial furrows depressed and prominent, curving toward each other posteriorly but not joining, leaving a nearly parallel-sided posterior axial ridge continuing almost to posterior margin of pygidium. Axial lobe sloping steeply to posterior axial ridge but without a furrow separating them.

Entire pygidium heavily tuberculated and granulose but without spines; tubercles irregularly scattered and of various sizes.

*Remarks.*—This species differs from *E. eriopis* (Hall) in having nearly parallel longitudinal glabellar furrows, and an evenly inflated anterior glabellar lobe which is not depressed posteriorly. The posterior axial furrows of the pygidium do not flare laterally nor do they bear large axial spines.

*Occurrence.*—Locality 6.

*Types.*—Holotype, an incomplete cephalon, UMMP 36172; paratypes, an incomplete cephalon, UMMP 36173, and an incomplete pygidium, UMMP 36148; unfigured paratype, an incomplete pygidium, GSC 14759; unfigured paratype, an incomplete cephalon, USNM 549509.

## SUMMARY AND CONCLUSIONS

In this report 125 species and 3 subspecies have been described and illustrated from the Formosa reef limestone of southwestern Ontario. Of these, 31 species and two subspecies are new, 35 species and one subspecies have been placed in previously established species, and 59 species are uncertain as to taxonomic placement either because the specimens are too poorly preserved or insufficient numbers of specimens have been collected for description of a new species.

The higher taxonomic placement of the new species is as follows:

1. One species in the Family Receptaculitidae (? Phylum Porifera). One new genus in this family is also described.
2. Seven species of stromatoporoids and one subspecies.
3. Two species of tetracorals including one which was placed by Grabau in a previously described species.
4. Fifteen new brachiopods including one which was placed by Hall and Clarke in a previously described species.
5. Three gastropods.
6. Three species and one subspecies of trilobites.

The higher taxonomic placement of the previously established species is as follows:

1. Two stromatoporoids
2. Two tetracorals
3. Nine tabulate corals
4. Fourteen brachiopods
5. Three pelecypods
6. Two gastropod species and one previously established subspecies.
7. One cephalopod
8. Two trilobites

The uncertain species are grouped as follows:

1. One species in the Family Receptaculitidae.
2. Fifteen tetracorals
3. Three tabulate corals
4. Eight bryozoa
5. Eleven brachiopods
6. Three pelecypods
7. Ten gastropods
8. Seven cephalopods
9. One trilobite

For purposes of attempting a paleontologic correlation of the Formosa reef limestone, use can be made of the known stratigraphic occurrence of the 36 previously described species and subspecies plus one tetracoral (*Synaptophyllum grabaui*, n. sp.) and one brachiopod (*Stenoscisma halli*, n. sp.). The stratigraphic distribution of these 38 species is as follows:

1. Twenty-six species (68%) are known only from rocks of Onondagan age.
2. Six species (16%) occur in both Onondagan and Hamilton strata.
3. Six species and one genus (*Stenoscisma*) were heretofore known only from the Hamilton.

Thus from a purely paleontologic viewpoint there is little doubt that the Formosa reef limestone is Onondagan.

The paleontologic evidence to support the stratigraphic age determination of the Formosa reef limestone as Detroit River is very meager. Of the 26 Onondagan species in the Formosa reef fauna only four are restricted to the Detroit River group while the remaining 22 species are distributed through the entire Onondaga limestone (both the *Amphigenia* and *Paraspirifer acuminatus* zones), the Bois Blanc, the Columbus, and the Jeffersonville limestone (see Cooper, *et al.*, 1942, p. 1774–1775; Ehlers, Stumm, & Kesling, 1951, p. 24).

The problem of paleontologic correlation is complicated by the fact that Grabau & Sherzer (1910) considered all fossils from the coral bed of the Oakwood salt shaft (p. 45) as belonging to the Anderdon limestone (see also Sherzer, 1913, fig. 21). More recent evidence indicates that the Anderdon overlies the Lucas (Ehlers, Stumm, & Kesling, 1951, p. 9–11) so that what Sherzer (1913, fig. 21) called the "Anderson" of the salt shaft is most likely the lower Amherstburg and the Anderdon is either not present in the salt shaft or has been included with the Dundee. Thus all fossils collected from the salt shaft and designated by Grabau & Sherzer (1910, p. 87–210) as from either the Anderdon or the coral bed are here considered to be from the Amherstburg dolomite.

The four species common to and restricted to the Detroit River group and the Formosa reef limestone with their stratigraphic occurrence are as follows:

1. *Syringostroma sherzeri* (Grabau)—Amherstburg dolomite.
2. *Synaptophyllum grabaui*, n. sp.—Amherstburg dolomite and questionably Anderdon limestone.
3. *Strophodonta homolostriata* Grabau—Amherstburg dolomite.
4. *Kozlowskiellina* (*Megakozlowskiella*) *submersa* Grabau—Amherstburg dolomite.

Thus upon first consideration the above paleontologic evidence suggests that the Formosa reef limestone is equivalent to the Amherstburg dolomite of the type area of the Detroit River group. However, the author has several reservations for not accepting this as conclusive evidence. First, the entire Detroit River fauna is in need of restudy; the Silurian affinities of many species stressed by Grabau & Sherzer (1910) and the state of preservation of much of their material cast doubts on the validity of many species determinations. Secondly, the true nature of the Anderdon fauna is very poorly known and is apparently so similar to the Amherstburg that Grabau & Sherzer miscorrelated the Amherstburg of the Oakwood salt shaft because of this similarity. Even with the corrections for this miscorrelation there are only six of Grabau and Sherzer's species restricted to the Anderdon while 10 species are found in both the Anderdon and Amherstburg and 43 species are restricted to the Amherstburg. Thus, there appear to be many more species in common between the Anderdon and Amherstburg than there are between the Amherstburg and the Formosa reef limestone. Thirdly, at the time Sherzer visited the exposures in the dry Livingstone channel he believed that the Amherstburg was the only formation exposed. Later study (Ehlers, Stumm, & Kesling, 1951, p. 9) suggests that the Lucas was also exposed since some species collected from the dry channel have been found only in the Lucas elsewhere. Therefore, perhaps several species indicated by Grabau & Sherzer (1910) as occurring in the Amherstburg are in reality from the Lucas. Additional study will be necessary before the extent of such errors can be determined.

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# ARTHROPODS FROM THE SYRACUSE FORMATION, SILURIAN OF NEW YORK

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ABSTRACT—Paleoecological interpretation of the Salina (Upper Silurian) section in New York state, based on lithologies and faunas, indicates a shallow aquatic environment with highly variable salinity. The Syracuse formation, which includes the major evaporite beds of the region, contains undescribed ostracodes, a trilobite (*Calymene* sp.), two species of *Ceratiocaris* (*Ceratiocaris* sp. and *C. nolli* n. sp.), and eurypterids assignable to five genera. *Eurypterus remipes flintstonensis* Swartz, *Ericopterus* sp., and specifically underterminable *Pterygotus* fragments occur in the upper Syracuse. *Pterygotus* fragments have also been found near the bottom of the formation. *Waeringopterus cumberlandicus apfeli* n. gen., n. subsp., is restricted to the lowest member of the Syracuse formation. A single fragment of a *Carcinosoma* has been found in the *Camarotoechia* zone, near the middle of the formation.

## INTRODUCTION

SINCE 1951, the writer has been engaged in a stratigraphic and paleontological study of the Salina group of central New York State. Certain aspects of this work indicate that a regional study of the faunas and stratigraphy of the entire Salina basin is in order. This is being done as rapidly as time and funds permit. Other phases of the investigation are completed and can be published as self-contained, though not independent, parts. This paper, which is based chiefly on a part of the writer's dissertation (1959), deals with the larger arthropods of the Syracuse formation. Ohio State University Museum numbers are indicated by the prefix "OSU."

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Thanks are due especially to Prof. Aurèle LaRocque of the Ohio State University, who advised the writer in all phases of his work. Mr. Erik N. Kjellesvig-Waering (Pan Argentine Oil Company) generously cooperated in discussion of the merostomes described here. The New York State Museum partly defrayed field expenses through honoraria in 1957 and 1958. The above parties are neither responsible for, nor necessarily in accord with the writer's conclusions.

## GEOLOGIC SETTING

In its type area, Onondaga County, New York, the Syracuse formation (Leutze, 1956, p. 1693) is composed of dolomites, evaporites, and shales. It is underlain by the Vernon shale and overlain by the Camillus shale. These three units, together with the superjacent Bertie formation, constitute the Salina group. The evaporite sediments and peculiar fauna of the Salina group reflect the intermittent (or partial) isolation of the basin from the open ocean. Overlying and underlying formations contain normal marine faunas. This indicates that both before and after the time of deposition of the Salina group there was little or no restriction of the basin. The Salina group is estimated to be about 900 feet thick in Onondaga County. The fauna contains forms which were able to survive the precarious living conditions of an evaporite basin. There are relatively few fossils, most of which are confined to a few thin zones. Within these zones, however, organic remains are locally very common. Three faunal zones have been recognized in the Syracuse formation (Leutze, 1956). The lowest of these was originally designated the "*Slimonia* zone." The supposed *Slimonia* of this zone is redescribed in the present paper as *Waeringopterus*, n. gen. The next higher zone is the *Camarotoechia* zone. The highest faunal zone is characterized by a winged pelecypod. The form in question may be conspecific with any or all of the following: *Pterinea prostriata* Ruedemann, *Pterinea flintstonensis* Prouty, *Pterinea jordani* Eaton, *Pterinea wayland-smithi* Fisher. The first of these appears to be an *Actinopterella*. The others are either species of *Actinopteria* or *Actinopterella*. Since internal features of the Syracuse form have

not been observed, it cannot be definitely classified but is close to *Actinopterella prostriata* (Ruedemann). To avoid complicating the stratigraphic terminology by the uncertainty surrounding this pelecypod, the writer, in the present paper, refers to this faunal zone by its original designation, the *Actinopteria* zone.

Throughout the Salina basin, the only phyla which are numerically important are Arthropoda, Mollusca and Brachiopoda. Of these, the arthropods are most numerous. Some beds contain vast numbers of ostracodes, and eurypterid remains locally carpet certain bedding planes. Whereas trilobites are very rare, the rarer arthropods (Eurypterida, Phyllocarida, Synziphosurina, and a single scorpion) are more common in Salina strata than in most Paleozoic rocks. Arthropods with chitinous exoskeletons are preserved only under exceptional environmental conditions. The repetition of beds containing chitinous arthropods in the Upper Silurian of New York is inextricably tied to the stratigraphy of the Salina rocks and the ecological factors they suggest. As envisioned by the writer, the Salina strike belt in New York closely approximates the original margin of a shallow basin. Slight fluctuations in sea level alternately flooded or exposed extensive tidelands. Concurrently, there were changes in salinity. Times of evaporation which brought about the deposition of salt and gypsum were followed by influxes of less saline water. Times of heavy rainfall drastically reduced the salinity over large areas, and brackish conditions were persistent near the mouths of streams. This reconstruction pictures an area where any given set of living conditions was ephemeral. Any type of life led a precarious existence under these circumstances. Scavengers were kept to a minimum. At times of high salinity, the water may have acted as a pickling brine, helping to preserve organic remains that might otherwise have been destroyed by bacteria.

It is hazardous to make any general statement about the salinity of the water in which the Salina faunas lived. It was extremely variable from place to place and from time to time. The writer hesitates to reopen the lengthy dispute on the habitat of the eurypterids. If conditions were as outlined, then the problem approaches an impasse. There is no way to determine whether the thin zones in which eurypterids are abundant represent lentils deposited under brackish conditions, or during times when the water was unusually salty. Throughout the Salina group, most zones of abundant eurypterid remains contain few other fossils. Conversely, beds which have relatively abundant brachiopods and molluscs contain only isolated eurypterids. It appears probable that the merostomes did not inhabit a normal marine environment. If they were not euryhaline, they must have been able to sense the direction in which it was necessary to migrate to follow the shifting salinity zone of their preference (*cf.* Clarke and Ruedemann, 1912, p. 110).

In the Syracuse formation, ostracodes are associated with the marine fossils, but there are some beds which contain countless millions of ostracodes and apparently nothing else. No attempt is made in this paper to systematically describe them. Most are species of *Leperditia*, but at least two other genera are present. Aside from Eurypterida and ostracodes, other arthropods are of sporadic and of somewhat unusual occurrence. One of three slabs on which phyllocarids have been identified shows ten or a dozen fragments, belonging to several individuals, crowded into an area only three inches square. Only two slabs preserving trilobite pygidia have been found by the writer, but each of these slabs shows two specimens.

## SYSTEMATIC DESCRIPTIONS

Phylum ARTHROPODA
Class TRILOBITA Walch, 1771
Order PHACOPIDA Salter, 1864
Suborder CALYMENINA Swinnerton, 1915
Family CALYMENIDAE Burmeister, 1843
Subfamily CALYMENINAE Burmeister, 1843
Genus CALYMENE Brongniart, 1822

CALYMENE sp.
Pl. 16, figs. 4,5

*Description.*—The description is based on four fragmentary pygidia and two glabellae, all collected from the same horizon and presumed to pertain to a single species. The glabellae are of almost identical size, 9 mm.

long by 9 mm. wide at the posterior lateral lobe. The figured specimen, an internal mold, is described. The axial lobe is subtrapezoidal, 6 mm. long, 4(?) mm. wide near the anterior end, and 2 mm. wide at the base. It is slightly inflated, has a smoothly rounded frontal margin, and is gently arched. The first lateral lobes cannot be distinguished. The second lateral lobes are small, located 2.5 mm. behind the anterior margin, and project about 1 mm. from the axial lobe. The posterior lateral lobes are well developed and are three times as large as the second laterals. The occipital furrow is a deeply impressed, rounded groove which sets off the occipital ring. The latter is 3 mm. wide, 1.5 mm. long, smoothly arched. A small fragment of the fixed cheek is preserved to the right of the glabella.

The best pygidium is an external mold (pl. 16, fig. 5). The five anchylossed segments have a half-width of 12 mm. and a length of 9 mm. Each of the pleurons is creased by a strong furrow. The margin is not crossed by either the furrows or the pleural grooves. The entire surface is granulose. The terminal segment has a bulbous, semiovate axial lobe, surrounded posteriorly by a narrow margin. The other pygidial specimens, an external mold on the same slab as the figured one and two internal molds on another slab, do not add materially to this description. Despite their poor preservation, all of the fragments are prominently arched.

*Occurrence.*—Specimens have been collected from the *Camarotoechia* zone at localities 23 and 48. The figured pygidium was found in a load of fill in Solvay, New York. There is no question as to its original horizon, as it is associated on the slab with *Camarotoechia litchfieldensis* (Schuchert) and a small color-banded specimen of *Pristeroceras timidum* Ruedemann. The slab is lithologically identical to the *Camarotoechia* zone beds. The fill was probably obtained from the vicinity of locality 200.

*Remarks.*—This material is too fragmentary for specific identification. The specimens pertain to *Calymene niagarensis* Hall or some closely related form such as *C. camerata* (Conrad). The latter differs from *C. niagarensis* chiefly by a lobe which projects from behind the eye, uniting with the third lateral lobe of the glabella. The presence or absence of this structure cannot be determined in the specimens at hand. From the stratigraphic standpoint, *C. camerata* appears to be a probable identification. In the Maryland section (Swartz *et al.*, 1923, p. 43), this species occurs in the Wills Creek formation in a thin but persistent faunal zone near the middle of the formation. This assemblage is the earliest marine Cayugan fauna in that state. The Syracuse *Calymene* occupies an analogus stratigraphic position in the *Camarotoechia* zone. Moreover, the associated fauna is similar in both states, having several species in common. There is not sufficient field evidence to show that the two faunal zones are identical, representing a single freshening of the Salina basin, but this is a possibility. *Calymene* is not known to recur in the New York Salina section. In Maryland, at one locality (Swartz *et al.*, 1923, p. 148), the genus has been found higher in the Wills Creek formation but is otherwise unknown below the Lower Devonian. *C. niagarensis* is unknown in post-Niagaran strata, though Eaton (1924, p. 111) questionably identified this species from the Vernon shale.

*Figured specimens.*—OSU 22763, internal mold of glabella; OSU 22764, external mold of pygidium. One glabella and two pygidia in New York State Museum.

Class MEROSTOMATA Dana, 1852
Subclass EURYPTERIDA Burmeister, 1845
Superfamily EURYPTERIDACEA Burmeister, 1845
Family HUGHMILLERIIDAE Kjellesvig-Waering, 1951
Genus WAERINGOPTERUS n. gen.

*Generic diagnosis.*—Moderately small eurypterids having a lanceolate body, the outer surface of which is either smooth or is ornamented with minute semilunar scales. Prosoma subquadrate, with reniform compound eyes located at anterolateral corners. Compound eyes angulated on the inner margins so as to parallel corresponding borders of the prosoma. Powerful swimming legs, in which the fourth and sixth joints (femur and tibia) are relatively elongate. Narrow paddles composed of seventh and eighth joints. Metastoma cordate, subel-

liptical, with very slight anterior indentation. Walking legs spinose, short, stout. Ensiform telson slightly expanded. Chelicerae and genital appendage unknown.

The genus *Waeringopterus* differs from other genera of the Hughmilleridae in the more rapid constant rate at which the postabdomen tapers, the slender outline of the metastoma, and in the structure of the paddles. In addition to these features, it differs from *Hughmilleria* by its rectangular prosoma. From *Hughmilleria*, *Slimonia*, and *Lepidoderma*, it can be distinguished by the elongate fourth joint of the swimming leg. The paddles of *Waeringopterus* are proportionately larger and more powerful than those of *Grossopterus*, and the anterolateral corners of the prosoma are not expanded as in that genus. *Salteropterus* and *Hastimina* are too imperfectly known to permit close comparisions, but the ornamentation of both these genera consists of pointed triangular scales. *Salteropterus* has a broadly expanded telson which is abruptly constricted, followed by a long slender projection. The telson of *Hastimina* is hastate, and has a median portion sharply differentiated from the lateral flanges. Thus the telsons of both genera, as well as their ornamentation patterns, are distinct from *Waeringopterus*.

*Type species.—Waeringopterus cumberlandicus* (Swartz).

*Remarks.—Waeringopterus* may provide a place for a number of fragmentary specimens reported in the literature. These are all subquadrate prosomas which have been questionably assigned to *Pterygotus* for lack of any really adequate genus. *Pterygotus? vernonensis* Ruedemann (1920, p. 214–215, pl. 1, figs. 1,2) was based on two small head shields from the lower part of the Vernon shale at Pittsford, New York. Both are poorly preserved, but in outline, general proportions, and position of eyes, they resemble *Waeringopterus* more closely than any known *Pterygotus*. Ruedemann, (p. 215) commented that the specimens suggested *Slimonia*. He also noted their similarity to certain prosomas found in the Ordovician of New York, and stated (p. 215), "It is . . . thought that these carapaces merely belong to a group of *Pterygotus* of possible subgeneric rank, to be segregated with more complete material."

Probably the Ordovician material to which he referred was *Pterygotus prolificus* Clarke and Ruedemann (1912, p. 382–383, pl. 86, figs. 1–5). This form may contain several species or even genera. The authors remarked, ". . . It is, however, possible that more than one species is comprised in this preliminary description . . . There is an element of difference [in the outline of prosomas of different specimens] that suggests the presence of more than the . . . species of *Pterygotus* here described and a distinction between the round and squarish carapaces. . . We have selected the squarish specimens as typical of *P. prolificus*." Only figures 1 and 3 on plate 86 would qualify as "typical" under this distinction, and they could as easily represent *Waeringopterus* as *Pterygotus*.

Swartz *et al.* (1923, pl. LXVII, fig. 5) illustrated a prosoma having the same outline and proportions as *Waeringopterus*. This specimen was collected from a shale lentil in the Keefer sandstone (Clinton) near Hancock, Maryland, and submitted to Clarke and Ruedemann for identification. They (1912, p. 88) stated, "The [carapace] is either a distorted *Dolichopterus*, comparable to *D. otisius*, or a *Pterygotus*, approaching a *Slimonia* in outline."

The repeated reference to *Slimonia* is noteworthy, for the writer originally (1956, p. 1696) identified his specimens as a new species of *Slimonia*. This was based chiefly on the rectangular head shield and marginal eyes common to both genera.

*Peterygotus? priscus* Ruedemann is known from a single prosoma and associated fragments (Ruedemann, 1942, p. 27, fig. 6(2)). In response to an inquiry about this form, Mr. Erik N. Kjellesvig-Waering replied, " . . . *Pterygotus? priscus* is likely not a Pterygotidae . . . on the basis of the prosomal appendages which, if they are walking legs, are too fat for *Pterygotus* and if swimming legs, much too narrow . . . It is either a dolichopterid, and the eyes aren't exactly right for that, or [*Waeringopterus*]" (personal communication, 1958).

Should it eventually be found that all these doubtful forms belong to *Waeringopterus*, then it will be necessary to revise the generic diagnosis so as to include species whose eyes are not angulated on the inner margins. Probably other minor amendments would also be found appropriate.

### WAERINGOPTERUS CUMBERLANDICUS (Swartz), 1923

*Dolichopterus cumberlandicus* SWARTZ, 1923, p. 717–718, pl. LXVI, figs. 3,4; pl. LXVII, figs. 1,2. LEUTZE, 1960, p. 1024–1025, text-fig. 1.
*non Dolichopterus cumberlandicus* SWARTZ, 1923, pl. LXVII, fig. 3.

*Description.*—Same as for the subspecies.

*Occurrence.*—Upper Silurian of eastern North America. Two subspecies are known, one in the Wills Creek formation of West Virginia, the other in the Syracuse formation of central New York.

### WAERINGOPTERUS CUMBERLANDICUS CUMBERLANDICUS (Swartz), 1923
not figured

*Dolichopterus cumberlandicus* SWARTZ, 1923, p. 717–718, pl. LXVI, figs. 3,4; pl. LXVII, figs. 1,2. LEUTZE, 1960, p. 1024–1025, text-fig. 1.

*Description.*—Most of what can be ascertained from known specimens of this form has already been described and illustrated. There are, however, minor details of the telson which are important in the establishment of the subspecies. The telson of *W. cumberlandicus cumberlandicus* is ventrally carinate. It is only slightly constricted behind the point of attachment. A distinct sulcus just inside the margins of the segment sets off a narrow flange along the borders. These features were illustrated by Swartz *et al.* (1923, pl. LXVI, fig. 4) and are clearly visible on one of the writer's specimens (Chicago Natural History Museum PE 6132). The latter is a complete telson 46 mm. long which expands only slightly before it tapers to a point. It is relatively long in proportion to its width (6mm. maximum). The outline of the telson of *W. cumberlandicus cumberlandicus* is reminiscent of a crusader's broadsword.

The prosoma for which measurements were given by Swartz *et al.* (1923, p. 718; no doubt pl. LXVI, fig. 3) is 34 mm. long by 45 mm. wide. This compares remarkably well with the largest specimen of *W. cumberlandicus apfeli* from the Syracuse formation (33? by 45? mm.), especially since both are distorted. The correspondence in size, proportions, parts preserved and position of swimming legs between figure 1, plate LXVII (Swartz *et al.*, 1923) and figure 8 on plate 15 of the present paper is striking.

*Occurrence.*—*W. cumberlandicus cumberlandicus* is known from the upper part of the Wills Creek formation in West Virginia at Riverside and Cedar Cliff.

*Remarks.*—This form was originally described on the basis of a small collection of fragmentary material. The writer subsequently obtained additional specimens from the type locality. One prosoma in this second group (Leutze, 1960, fig. 1) demonstrates that Swartz's reconstruction of the anterior margin was too convex. Unfortunately, the small suites of specimens do not ellucidate details of the paddle or other parts customarily used for generic diagnosis. Assignment to the genus *Waeringopterus* rests on the new supspecies. *W. cumberlandicus apfeli.* The latter is so similar to *W. cumberlandicus cumberlandicus* as to leave no doubt of their close relationship. Since the paddles and metastoma of *W. cumberlandicus apfeli* are known, the West Virginia subspecies can be confidently placed in the same genus.

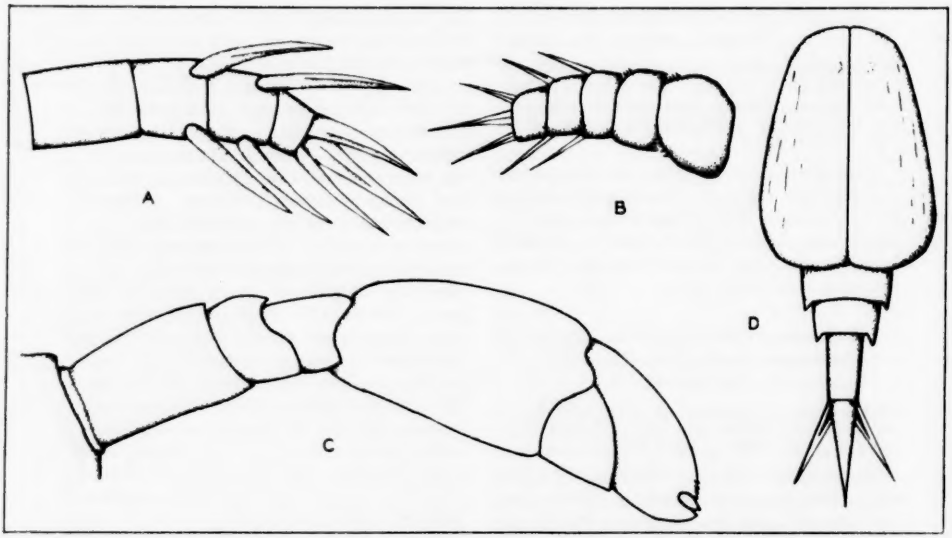
*Type.*—Holotype selected by Swartz *et al.* (1923, pl. LXVI, fig. 4). Paratypes: pl. LXVI, fig. 3; pl. LXVII, fig. 1,2. Hypotypes: Chicago Natural History Museum PE 6131 (prosoma) and PE 6132 (telson).

### WAERINGOPTERUS CUMBERLANDICUS APFELI, n. subsp.
Pl. 15, figs. 1–13, text-figs. 1A–C

*Slimonia* n. sp., LEUTZE, 1956, p. 1695–1696.

*Description.*—General outline lanceolate. The prosoma is rectangualr, almost square, with a length to width ratio of about 1:1.20 to 1:1.22. The larger specimens so far collected are distorted. Their measurements cannot, therefore, be completely relied upon but the subspecies appears to retain prosomal proportions which are only a little broader than long throughout ontogeny. The anterior margin of the head shield is essentially straight, with a slight median indentation on most specimens. Anterolateral corners are abrupt. Lateral margins are straight and the sharp posterolateral angles are square. The posterior margin is slightly convex anteriorly along its mid-portion.

Compound eyes are prominent, reniform, a little less than one-third as long as the prosoma. They are located marginally, their outward convexity froming the posterior part of the anterolateral corners. Anteriorly, they curve within the borders of the




TEXT-FIG. 1—A–C. *Waeringopterus cumberlandicus apfeli* n. gen. n. subsp. A, ventral view of fourth (?) walking leg, reconstruction based on counterpart of holotype (OSU 22760), about ×6. B, second or third walking leg, dorsal view, about ×5. (Same as plate 15, fig. 11.) C, swimming leg, reconstructed from several specimens, about ×3.5. D, *Ceratiocaris nolli* n. sp. Reconstruction based on associated fragments from locality 12, about ×5.

prosoma. The inner margin of each eye is sharply angulated about two-thirds of the way back, so that the posterior third of the eye parallels the lateral margin whereas the anterior portion parallels the anterior margin. In this respect, the eyes are similar to those of *Grossopterus overathi* (Gross).

Median ocelli are small, slightly raised, but are seldom preserved. They have central pits. The ocelli are located axially, midway between two imaginary lines, one connecting the centers of the compound eyes, the other connecting their posterior ends.

The walking legs are short and stout. They increase in length from front to back. All are spinose, with two spines attached near the distal corners of both the fifth and sixth joints. The seventh joint bears three longer spines. Short delicate spines are also present on the dorsal surface at the distal ends of the third and fourth joints (text-fig. 1B).

The swimming legs are long and powerful. The coxa is proportionately large, rectangular, resembling that of *Hughmilleria socialis* Sarle. The trochanter and prefemur are simple articulating rings. The femur is elongate, as in *Dolichopterus*, with a breadth to length ratio of 1:1.8. The patella is short and has a hooked anterodistal corner. The tibia is relatively long, with a convexly arcuate anterior margin. The tarsus is broad, with the greatest surface area of any joint. Triangular lobes are prominent, well developed. The ultimate joint (pretarsus) is of moderate size, semielliptical, and bears a small claw. Immediately anterior to the claw are several small marginal serrations.

The metastoma is approximately twice as long as wide. Its greatest width is near the anterior end, and from here it tapers slowly posteriorly to a rounded point. Anteriorly, it is blunt, with a very small median indentation (pl. 15, figs. 12,13).

The thorax is only slightly inflated, being almost exactly as wide as long. The greatest width is at the fourth tergite. From this segment, the preabdomen tapers increas-

TABLE 1—PROSOMAL DIMENSIONS OF *Waeringopterus cumberlandicus apfeli* N. GEN. N. SUBSP.

| Specimen | Maximum length | Width at genal angles | Eye | | Remarks |
|---|---|---|---|---|---|
| | | | Length | Width | |
| OSU 22753 | 9.5 | 13 | 3 | 1.5 (?) | Pl. O, fig. 5 |
| OSU 22777 | 12 | 14 | 4.5 | 1.5 (?) | Unfigured paratype |
| OSU 22757 | 13.5 | 18 (?) | 5.0 | 2.0 | Pl. O, figs. 9–10 |
| OSU 22759 | 19 | — | 6.5 | 3.0 | Pl. O, figs. 12–13 |
| OSU 22778 | 33 (?) | 42 (?) | 9.5 | 4.5 | Largest paratype |

All dimensions are in millimeters.

ingly forward to its junction with the prosoma, and less abruptly posteriorly. The first tergite is short, with a width to length ratio of about 8:1. It is convex in an anterior direction, especially along the posterior margin near the center. The ends turn slightly forward. The other tergites are relatively straight, rectangular, and half again as long as the first. The last segment of the preabdomen (7th tergite) has prominent epimers.

The postabdomen tapers posteriorly at a constant rate more pronounced than in others members of the Hughmilleriidae. Each of its segments has small epimers except for the pretelsion. The latter is deeply forked to receive the telson, and the epimers comprise nearly one-third of the total length of the segment. In natural relief, the pretelson is arched dorsad. A central lobe lies between two less prominent lateral lobes which are in turn flanked by the flat epimers.

The telson is ensiform, triangular in cross section, with a dorsal(?) carina. Immediately posterior to the point of attachment, the telson is constricted. It slowly expands for three-fifths of its length, and finally tapers rapidly to a sharp point. The outline strongly suggests the proportions of the short roman sword. The posterior one-sixth of the telson has small marginal barbs, as in *Slimonia*.

*Dimensions.*—Only two nearly complete specimens have been collected (pl. 15, figs. 5,8). The larger of these is an average adult, whereas the smaller one is unusually small. Most of the fragments collected seem to pertain to individuals about the size of the larger specimen or a little smaller. Prosomas are the part commonly preserved in measurable condition, so the dimensions of several are given to suggest the approximate range of size to be expected.

The largest specimen (OSU 22778; see table 1) is distorted and was first mistaken for a *Carcinosoma*. The anterior portion is compressed in such a way as to present a trapezoidal outline, so its dimensions are not completely reliable, but have been included to suggest the maximum size attained by the subspecies.

*Ornamentation.*—The ornamentation of *W. cumberlandicus apfeli* is somewhat problematical. In the bed from which most of the specimens have been collected, isolated thoracic segments showing minute semilunar scales have been found. Similar ornamentation has been observed on a specimen (Chicago Museum of Natural History PE 6133) from one of Swartz's localities for *W. cumberlandicus cumberlandicus*. None of these can be definitely related to *Waeringopterus*. Well preserved specimens show no ornamentation whatsoever. Yet the ornamented fragments do not seem to pertain to any other genera or species identified from the same beds. The writer hesitantly assigns them to *Waeringopterus*.

*Occurrence.*—*Wearingopterus cumberlandicus apfeli* is abundant in a single thin bed of argillaceous dolomite near the bottom of the Syracuse formation. This bed has been traced from Laird Corners (locality 255), Onondga County, New York, to Clockville (locality 139), Madison County. Twelve miles west of Laird Corners, a prosoma of *W. cumberlandicus apfeli* (OSU 22777) was found in dolomitic shale at the town of Port Byron, Cayuga County (locality 256). This specimen came from an undetermined stratigraphic horizon very close to the bottom of the Syracuse formation. The terminal joint of a swimming foot of *W. cumberlandicus apfeli* (OSU 22792) was found in a talus slab of Syracuse dolomite at Creager Bridge,

Wayne County. From Creager Bridge (locality 252) to Clockville is about 45 miles. Fragments of *Waeringopterus* have also been identified in a conglomertic dolomite about eight feet lower in the section than the bed in which specimens are abundant. The latter occurrence has been confirmed only at Syracuse (locality 87), but at several other localities there are eurypterid fragments, probably belonging to this genus, in a similar lithology at the same horizon. *Waeringopterus* has been found in the Syracuse formation at the following localities: locality 4 (in talus); locality 7; locality 11; locality 15; locality 23; locality 87; locality 133; locality 139; locality 252 (in talus); locality 255; locality 256.

*Remarks.*—The description is based on several thousand fragmentary specimens collected over a period of five years. Most of the specimens consist either of disarticulated thoracic segments, or of head shields with the first tergite attached. Only two specimens of the walking legs are known, and in only four specimens is the paddle complete enough for detailed study. These facts show that few of the specimens represent entire animals buried intact. Probably they are molts or cadavers that were washed by currents and waves and became disarticulated before burial. The holotype may be an exception, for insofar as the slab shows, it seems to represent an entire individual with all the appendages attached. Some concentrations of the fragments suggest windrows accumulated in shallow ripple troughs. The argillaceous dolomite in which they are preserved does not show distinct ripple marks, though silty lentils within the bed are faintly cross bedded.

In the slabs examined from the highly productive bed, only two other types of organic structures have been observed. Carapaces of leperditiid ostracodes are present but exceedingly rare. A trail of some shovelling type of animal has also been found. The trail is a long trough-like depression, horizontal to the bedding, 21 mm. wide and 3 mm. deep. Its size is not inconsistent with the dimensions of *W. cumberlandicus apfeli*. This suggests that *Waeringopterus* was a mud-groveller, similar to the present-day *Limulus*.

*Types.*—Holotype, right half of the prosoma showing compound eye, walking legs, and metastoma, with parts of paddle and tergites attached, OSU 22759. Counterpart mold showing paddle and walking leg, OSU 22760. Paratypes, OSU 22749–22758, 22777, 22792. Ornamented fragment, OSU 22783. Counterparts of OSU 22752, 22753, 22757, 22758, and 22783, together with suite of unfigured paratypes, in New York State Museum.

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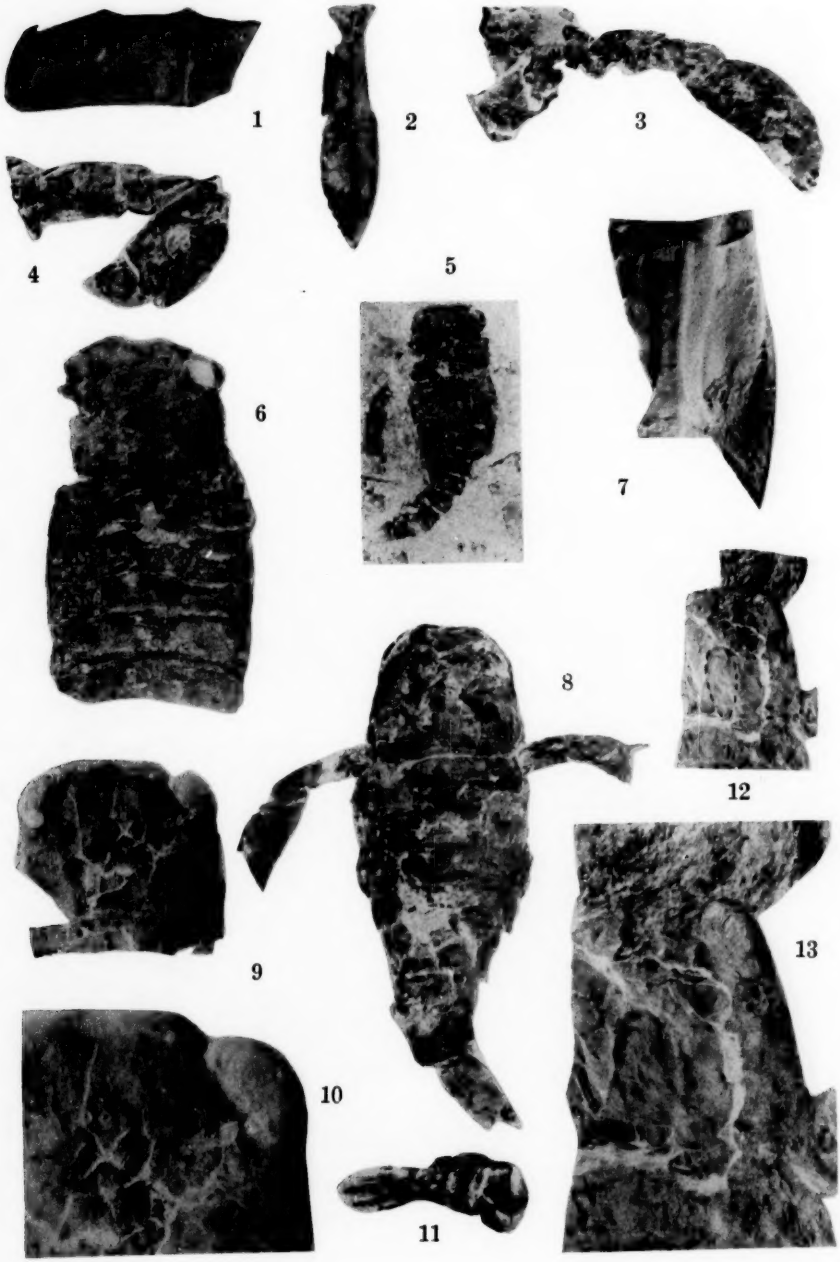
EXPLANATION OF PLATE 15

FIGS. *1–13*—*Waeringopterus cumberlandicus apfeli* n. gen. n. subsp. *1*—genital operculum as viewed from the interior; locality 11, ×1.9. *2*—mold of telson; locality 11, ×1.9. *3*—carbonaceous film showing complete paddle; locality 133, ×2. *4*—another paddle showing better preservation, but lacking terminal joint; locality 23, ×2. *5*—small individual, dorsal view; locality 23, ×1. *6*—dorsal view of a prosoma with six tergites attached; locality 11, ×1.1. *7*—mold of dorsal side of pretelson showing natural relief; locality 139, ×2. *8*—ventral view, nearly complete specimen. Appendages are broken away so that the under side of the head shield is seen; locality 23, ×1. *9*—dorsal view of a prosoma with ocelli preserved; locality 11, ×1.9. *10*—same, ×4. *11*—carbonaceous film of well preserved but fragmentary walking legs; locality 23, ×2. *12*—dorsal aspect of prosoma with walking legs and part of paddle attached. Cut away to show metastoma; locality 15, ×1. *13*—same, ×2. All specimens are from the Transition member, Syracuse formation. The original of figs. 12–13 is the holotype, all others are paratypes. OSU 22749–22759, in sequence of figures on this plate.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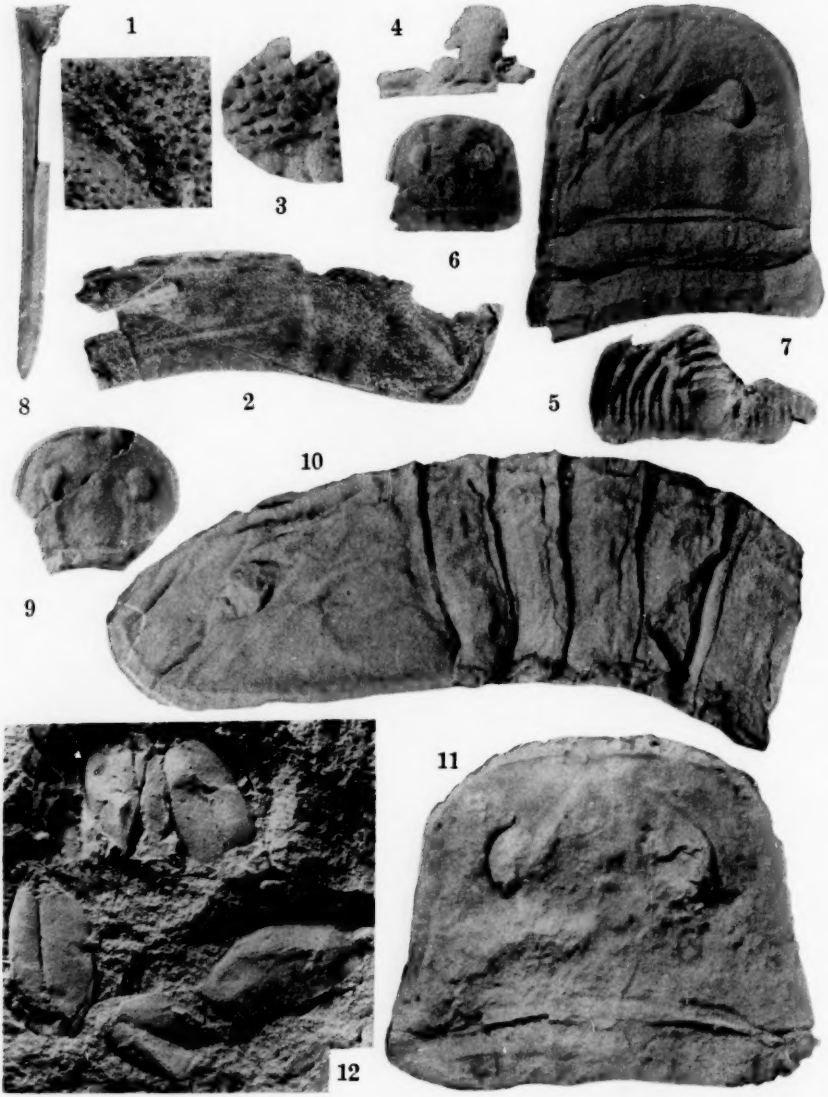
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Family EURYPTERIDAE Burmeister, 1845
Genus EURYPTERUS De Kay, 1825
EURYPTERUS REMIPES FLINTSTONENSIS Swartz, 1923
Pl. 16, figs. 6–8,10,11

*Eurypterus flintstonensis* SWARTZ, 1923, p. 716 pl. LXVI, fig. 1: ?pl. LXVII, fig. 3; WOODWARD, 1941, p. 263; KJELLESVIG-WAERING, 1950, p. 226.

*?Dolichopterus cumberlandicus* SWARTZ (part) 1923, pl. LXVII, fig. 3.

*Eurypterus remipes flintstonensis* SWARTZ, KJELLESVIG-WAERING, 1958, p. 1126.

*Eurypterus remipes* DeKay, LEUTZE, 1956, p. 1967.

*?Eurypterus remipes swartzi* KJELLESVIG-WAERING, 1958, p. 1134–1135, pl. 143, fig. 3; pl. 145, fig. 2; text-figs. 12–14.

*Eurypterus remipes* subsp. KJELLESVIG-WAERING, 1958, p. 1132,1134.

*Description.*—Prosoma subrectangular, length to width ratio ranges from about 1:1.33 to 1:1.66. The anterior prosomal margin is very slightly convex. Broadly rounded anterolateral angles approximate 90°. Lateral margins are straight, with an almost imperceptible divergence posteriorly. Genal angles are sharp right angles. The posterior margin is straight for a little less than one-tenth of its extent on each side of the posterolateral angles, then curves gently anteriorly. Steeply inclined shovelling rim prominent. The occipital furrow is deeply impressed, setting off a narrow occipital band.

The small compound eyes are reniform and rise somewhat above the general surface of the prosoma. They are located one-fifth farther from the anterior margin than from the nearer lateral margin. The distance between the eyes is twice the distance from their anterior ends to the frontal margin. The long axes of the eyes converge anteriorly at an angle of approximately 20°. Palpebral lobes are either greatly reduced or are not distinctly delineated.

The median ocelli have not been observed, but the low ocellar mound is located centrally, just anterior of a line connecting the posterior ends of the compound eyes.

Tergites of the preabdomen are straight, rectangular, with corners only slightly blunted. The first tergite is relatively short, less than one-quarter the length of the prosoma. Its posterior margin turns anteriorly about 20° at the distal ends. Centrally, both the anterior and posterior margins are slightly convex anteriorly. Each of the succeeding four segments is longer than the segment preceding it. Their posterior margins are more nearly straight than that of the first tergite. There appears to be very little widening of the thorax in the first five tergites, suggesting that the posterior margin of the prosoma approaches the maximum width of the thorax.

The prosoma and first five tergites have no ornamentation.

Dimensions of the Syracuse formation

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EXPLANATION OF PLATE 16

FIGS. *1–2*—*Carcinosoma* sp. Fragment of sixth (?) tergite showing ornamentation and color pattern; locality 133. Fig. 1, ×3; fig. 2, ×1. OSU 22661.

*3*—*Pterygotus* sp. Fragment showing typical ornamentation pattern; locality 25, ×2. OSU 22762.

*4,5*—*Calymene* sp. Glabella from locality 23, ×2. Concave mold of pygidium from Solvay, ×1.5. OSU 22763–22764.

*6–8,10,11*—*Eurypterus remipes flintstonensis* Swartz. Figs. 6, 7, and 11 are prosomas; 8 is a telson, 10 is a prosoma with first five tergites. Fig. 6, locality 257, ×2; fig. 7, locality 12, ×2; fig. 8, locality 202, ×1.7; fig. 10, locality 12, ×2.1; fig. 11, locality 103, ×2. OSU 22765–22767, 22769–22770.

*9*—*Erieopterus* sp. Fragmentary prosoma; locality 95, ×2. OSU 22768.

*12*—*Ceratiocaris nolli* n. sp. Carapaces and, in the northwest quadrant, thorax and telson; locality 12, ×2. OSU 22771–22776.

TABLE 2—PROSOMAL DIMENSIONS OF *Eurypterus remipes flintstonensis* SWARTZ

| Specimen | Maximum length | Width at genal angles | Major diameter of eye | Remarks |
|---|---|---|---|---|
| OSU 22765 | 8 | 11 | 2 | Pl. 16, fig. 6 |
| Holotype | 12 | 20 (?) | 4 | Pl. LXVI, fig. 1 |
| OSU 22766 | 18 | 24 (?) (right half ×2) | 4 | Pl. 16, fig. 7 |
| OSU 22770 | 21 | 32 | 5 | Pl. 16, fig. 11 |

All dimensions are in millimeters.

specimens assigned to *E. remipes flintstonensis* and Swartz's Tonoloway formation holotype are given by table 2.

In addition to the features which can definitely be attributed to this form, isolated fragments of *Eurypterus* are found in the same bed and presumably pertain to the same species. Among these fragments are postabdomal segments bearing a double row of pointed scales. The ornamentation on these segments resembles that on the corresponding parts of *E. remipes remipes* DeKay, *E. remipes tetragonophthalmus* Fischer deWaldheim and *E. remipes lacustris* Harlan.

A slender styliform telson 34 mm. long with a dorsal carina which bifurcates near its proximal end probably also belongs to *E. remipes flintstonensis*. The specimen in question (pl. 16, fig. 8) shows prominently serrate margins along the distal 14 mm. of its length. Unlike the telson of *E. remipes remipes*, the serrae decrease in size posteriorly.

*Occcurrence*—The holotype was collected from the lower third of the Tonoloway formation on Martin Mountain, Maryland (Swartz *et al.*, 1923, p. 143). This probably corresponds to the lower part of the Camillus shale in the New York section. Swartz *et al.* (1923, pl. LXVII, fig. 3) figured the swimming foot and walking legs of an *Eurypterus* from the top of the Wills Creek formation at Riverside, West Virginia. Kjellesvig-Waering (1958b, p. 1134–1135) established a new subspecies, *Eurypterus remipes swartzi*, on the basis of the distinctive swimming foot of the Riverside specimen. This is permissible under the international code. It seems probable, however, that his type belongs to the same species whose dorsal shield is known as *E. remipes flintstonensis*. A disarticulated joint was found in the *Actinopteria* zone of the Syracuse formation. The latter was sent to Mr. Kjellesvig-Waering. He reported (personal communication, 1958), "This is the triangular process of the 6th joint (past the coxa) of the swimming leg and looks a lot like my *E. remipes swartzi*."

Syracuse hypotypes were collected at localities 12, 103, 202, and 257. All except the specimen from locality 103 were found in the *Actinopteria* zone. The latter was found in a talus slab that, from its lithology and position on the slope, is believed to have come from a bed in the lower third of the Middle dolomite member but higher than the *Camarotoechia* zone.

Fragments of *Eurypterus* are common in the *Actinopteria* zone in the vicinity of Syracuse, and were reported from the same (?) horizon in western New York (Hartnagel, 1907, p. 32). (Hartnagel mistook the formation as Bertie. He was misled by the position of the minable gypsum, which occurs here in the Syracuse formation. The best grade of gypsum in western New York is in a bed apparently equivalent to the Upper clay member. Most of the commercial gypsum of Onondaga County and the Cayuga Lake district is in the Scajaquada member of the Bertie.) Dale (1953, p. 122–123) reported an *Eurypterus* from the abandoned quarry on Crow Hill near Utica, but it has been impossible to locate the specimen he described. The quarry is in the Middle dolomite member of the Syracuse formation (Leutze, 1959, pl. V). The writer has been unable to find other specimens at this quarry.

It is, of course, uncertain how many of these specimens pertain to *E. remipes flintstonensis*, but all were found within a relatively narrow stratigraphic zone, from the

upper half of the Syracuse formation, the upper Wills Creek, and lower Tonoloway. Probably all belong to the same form.

*Remarks.*—The Syracuse specimens show differences which might be sufficient to establish a new subspecies. When they are considered as a group, there is as much difference between any two individuals as there is between any one and the holotype of *E. remipes flintstonensis*. Until more diagnostic material is collected, it seems best to assign the Syracuse material to the established subspecies. The additional arguments of geographic proximity and similarity of stratigraphic horizon also suggest that a conservative view is warranted for the present. The greatest difference among the specimens is in outline of the prosoma, from trapezoidal to rectangular. This may be due to distortion during preservation. Upon crushing, the arched rectangular head shield would spread, especially along the base, to a trapezoidal outline. Swartz's holotype shows considerable difference in the genal angles on opposite sides of the prosoma.

*E. remipes flintstonensis* is distinguished from other known members of the family by its broad rectangular prosoma which is nearly equidimensional at maturity. The eyes are relatively small, and their anterior ends are approximately one eye-length from the anterior margin of the prosoma, unusually far forward on the head. Other members of the genus which have similarly small eyes, such as *E. pittsfordensis* Sarle, have shorter, more rounded prosomas. There is one exception to this generalization. *E. remipes quebecensis* Kjellesvig-Waering has a comparable outline and length to width ratio. It differs in its very small eyes. (Length of eye to length of prosoma is 1:5.7, whereas the largest hypotype of *E. remipes flintstonensis* has a ratio of 1:4.22. These ratios are not strictly comparable, since the holotype of *E. remipes quebecensis* is twice the size of the largest known specimen of *E. remipes flintstonensis*.) The eyes are much closer to the anterior in all specimens of *E. remipes flintstonensis* than in *E. remipes quebecensis*. The short, pointed spines along the posterior margin of the prosoma of the Gascons formation specimen are another distinguishing criterion. *E. remipes laculatus* Kjellesvig-Waering, a somewhat similar form found in the Cobleskill dolomite, has the eyes located relatively farther back on the prosoma.

All of the material attributed to *E. remipes flintstonensis* indicates that it was a small form, less than 20 cm. in overall length at maturity. The species has several points of similarity to *E. pittsfordensis* Sarle, a larger form to which it is no doubt closely related (*cf.* especially Clarke and Ruedemann, 1912, pl. 13, fig. 5). Kjellesvig-Waering (1958b, p. 1134) has presented evidence which indicates that *E. pittsfordensis* was ancestral to the entire *E. remipes* group.

The median ocelli occupy a small mound cuse specimens suggests that they are either disarticulated, waterworn fragments of dead individuals or molted exoskeletons.

*Types.*—Hypotypes, OSU 22765–22767; 22769–22770; 22782. Counterparts of 22765 and 22769 in New York State Museum.

Genus ERIEOPTERUS Kjellesvig-Waering, 1958

ERIEOPTERUS sp.

Pl. 16, fig. 9

*Description.*—One fragmentary prosoma of an *Erieopterus* has been found. It is 9.5 mm. long, 13 mm. wide, and retains the arched form of the original. The anterior margin is broadly curved, lateral margins straight insofar as can be seen. The genal angles are missing. The general form is short and wide, relatively rectangular. A low opthalmic ridge is developed posterior to each eye. A less distinct cardiac lobe is present.

The compound eyes are reniform, protuberant, rising prominently above the general surface of the prosoma. They are 3 mm. long in greater diameter, located intramarginally two-thirds of the way forward on the prosoma, about equally distant from anterior and lateral margins. The eyes do not converge anteriorly.

The median ocelli occupy a slight mound slightly forward of a line connecting the midpoints of the compound eyes.

*Occurrence.*—Found in the *Actinopteria* zone of the Syracuse formation at locality 95.

*Remarks.*—The specimen is similar to *E. laticeps* (Schmidt), but proportionately narrower. It probably represents a new species to be described when more material becomes available.

*Figured specimen.*—OSU 22768.

Family PTERYGOTIDAE Clarke and Rudemann, 1912
Genus PTERYGOTUS Agassiz, 1839
PTERYGOTUS sp.
Pl. 16, fig. 3

*Description.*—In the *Actinopteria* zone, mingled with fragments of *Eurypterus remipes flintstonensis*, there are many bits of integument prominently ornamented with raised semilunar scales. Most of these fragments are less than a centimeter square, and are specifically undeterminable. The ornamentation is characteristic of *Pterygotus*. A single entire sternite (OSU 22779) has been found. It is 12.1 cm. wide by 3.1 cm. long. The anterior margin is closely ornamented with scales up to 1.25 mm. in length. Axially, the scales are more widely spaced and extend farther towards the posterior margin than on other parts of the plate. The posterior half of the sternite is smooth. This segment of a *Pterygotus* evidently belonged to an individual with a length of not less than 55 cm.

A mold of an ovoid eye (OSU 22781) with fragments of the prosoma attached was found at the base of the Syracuse formation at locality 87. Major diameter of the eye is 9.5 mm. The minor diameter is 6 mm. The specimen preserves the natural relief of the original, and retains a vestige of the facets. Although this eye is typical of *Pterygotus*, it might belong to any one of a large number of species of that genus.

*Occurrence.*—Most of the *Pterygotus* fragments have been obtained from the *Actinopteria* zone at localities 18, 25, 95, 96, 202, and 257. There are also many small pieces of thoracic segments associated with the eye described from locality 87. Erik Kjellesvig-Waering has recognized a fragment of the same genus in a slab sent to him from about 10 feet above the Syracuse-Vernon contact at locality 217. A single fragment found in talus at locality 136 may have come from part of the Middle dolomite member.

*Figured specimen.*—OSU 22762, fragment of integument showing the ornamentation of *Pterygotus*. Counterpart in New York State Museum.

Family CARCINOSOMATIDAE Størmer, 1934
Genus CARCINOSOMA Claypole, 1890
CARCINOSOMA sp.
Pl. 16, figs. 1,2

*Description.*—The illustrated fragment of a thoracic segment, probably the sixth tergite, displays the distinctive ornamentation of the genus *Carcinosoma*. This consists of raised, tongue-shaped scales. The specimen is 64 mm. wide, 18.5 mm. long near the middle, and is strongly curved anteriorly. The posterolateral angle is rounded, slightly obtuse. The anterolateral angle is damaged, but seems to have been relatively sharp, and was certainly less than 90°. The outline of the fragment suggests that if it were entire, it would have a width of 80 mm., and the rise of the posterior arc would be about 5 mm. There are small semilunar scales along the anterior 3 mm. This area, which was inserted under the immediately anterior segment, is sharply delineated by a single rank of short, crowded scales. Posterior to this line, the scales are larger, more elongate, and scattered evenly over the surface.

The entire specimen is stained a darker brown than the slab on which it is preserved. The central and anterior portion of each scale is dark brown, whereas the distal and lateral margins are very pale brown. The preservation of color in *Carcinosoma newlini* (Claypole) was described by Kjellesvig-Waering (1958a, p. 301–302). The color pattern shown by the Syracuse specimen is almost the reverse of that of *C. newlini*, in which only the tips of the scales are dark colored.

*Occurrence.*—The only specimen was found in the *Camarotoechia* zone of the Middle dolomite member at locality 133.

*Remarks.*—The *Camarotoechia* zone has been known to the writer longer than any other zone of the Syracuse formation. Extensive collecting from its outcrop has yielded only one eurypterid fragment, and this belonging to a genus unknown elsewhere in the formation. *Carcinosoma* has been previously recorded from the New York Cayugan in the Williamsville member of the Bertie, where *C. scorpionis* (Grote and Pitt) has

been found in Erie County. The genus is represented in the Lockport of central New York by *C. vaningeni* (Clarke and Ruedemann). At the locality where the present fragment was collected, the *Camarotoechia* zone is very fossiliferous. *Hormotoma rowei* Swartz and inarticulate brachiopods are unusually abundant. This may suggest shallower water than other exposures of the zone in Onondaga County. The counterpart shows *Orbiculoidea* sp. on the same surface as the *Carcinosoma* fragment and, on the underside, *Orbiculoidea* sp., *Camarotoechia litchfieldensis* (Schuchert), and part of an unidentifiable cephalopod.

*Figured specimen.*—OSU 22761, fragmentary tergite retaining color pattern. Counterpart in New York State Museum.

Class CRUSTACEA Pennant, 1777
Subclass MALACOSTRACA Latreille, 1806
Order PHYLLOCARIDA Packard, 1879
Suborder CERATIOCARINA Clarke, 1913
Family CERATIOCARIDAE Salter, 1860
Genus CERATIOCARIS M'Coy, 1849

CERATIOCARIS NOLLI n. sp.
Pl. 16, fig. 12; test-fig. *1D*

*Description.*—Carapace bivalved, pod shaped, with a straight hinge line. Ventral margins are bowed; valves more distended posteriorly than anteriorly. Ornamentation on carapace consists of faint terraced lines. Anterior adductor muscle scars are small, obscure. Penultimate abdominal segment has prominent epimers on the posterolateral corners. Telson styliform, sharply pointed, arched dorsad but not carinate. The cercopods are two slender, styliform segments, each of which has a median sulcus developed near the proximal end.

The description is based on a reconstruction of associated fragments found in the *Actinopteria* zone. A single small slab (pl. 16, fig. 12) shows five carapaces, one caudal assemblage with three thoracic segment attached, and several other disarticulated fragments. The largest carapace is 12 mm. long, the smallest is 6.5 mm. long. The telson and attached segments measure 8 mm. in length. Only one other specimen, probably belonging to the same species, has been found. The latter is a very fragmentary caudal assemblage with parts of two segments attached. It belonged to a relatively large individual, at least twice the size of the only other caudal assemblage, since the telson alone was about 10 mm. in length, but its condition is so poor that no exact measurements for comparative purposes can be made.

*Occurrence.*—All specimens are from the *Actinopteria* zone of the Syracuse formation at localities 12 and 202.

*Remarks.*—Several other species of *Ceratiocaris* have been reported from the Salina group in central New York. Hall (1859, p. 421–423) described three species from the Bertie formation (Williamsville member?) at Buffalo and one from the same formation (Fiddlers Green member?) at Forge Hollow. Clarke (1902, p. 92–95) described *Ceratiocaris praecędens* from the Pittsford shale. Ruedemann (1925, p. 73) established *C. clarkei* on three associated fragments found in a drift slab of "Bertie waterlime" from Canandaigua, New York. The Vernon shale (Ruedemann, 1920, p. 206) contains *C. salina* Ruedemann (1916, p. 92–93) as well as *C. praecedens* Clarke. The genus *Emmelezoe* has been recognized in the Pittsford, Vernon and Bertie (Clarke, 1902, p. 95–97; Ruedemann, 1920, p. 206; 1925, p. 74–75).

Phyllocarids with epimers on the thoracic segments are very uncommon. So far as is known, none of the previously reported Salina species has this characteristic. The pod shaped carapace with its reniform lateral outline as described and illustrated is considered sufficient to distinguish this species from all known species which do have epimers. Text-figure 1D represents a reconstruction based on the associated fragments.

The specific name is in honor of Mr. and Mrs. Herman Noll of Syracuse, New York, who helped the writer in the financially difficult times when he was a student doing field work.

*Types.*—The caudal assemblage (OSU 22771) is designated as the holotype, and the associated carapaces (OSU 22772 to 22776) are paratypes. The large unfigured specimen is OSU 22785.

CERATIOCARIS sp.
not figured

*Remarks.*—One valve of a *Ceratiocaris* which resembles *C. clarkei* Ruedemann

(1925, p. 73, pl. 23, figs. 2–4) was found in the Middle dolomite member at locality 200. This specimen has been sent to Erik Kjellesvig-Waering for study. It was found associated with small inarticulate brachiopods and *Cleidophorus salinensis* (Ruedemann). The occurrence of *Ceratiocaris* at this horizon is mentioned here in the interest of completeness.

### IDENTIFICATION OF LOCALITIES

Important localities mentioned in this article are located on the index map (text-fig. 2), and these places are briefly described below. The sections are most of the localities have been measured in detail. It is not practical to repeat the measured sections here, but they can be consulted in the writer's dissertation (1959). Correlation of selected sections is shown by text-figure 2. Quadrangles cited are U. S. Geological Survey topographic maps, 7½ minute series.

*Locality 4.*—Road cut on Breed Road, 0.3 mile S. of Canal Road, at elevation of about 490 to 500 feet. Camillus quadrangle. *Waeringopterus* sp. fragments in talus slabs of shaly dolomite.

*Locality 7.*—Ravine on N. side of Thompson Road, 0. 5. mile W. of Amboy. Camillus quadrangle. *Waeringopterus cumberlandicus apfeli* abundant in 7-inch shaly dolomite bed 22 feet 1 inch above Vernon-Syracuse contact.

*Locality 11.*—Small abandoned quarry about 100 yards S. of Bennet Road, 0.3 mile W. of Belle Isle. Camillus quadrangle. Bed of shaly dolomite 6 inches thick just above the lip of the quarry at an elevation of about 425 feet contains abundant well-preserved specimens of *Waeringopterus cumberlandicus apfeli.*

*Locality 12.*—Ravine of small tributary stream which crosses Canal Road 1.7 miles NNE. of Camillus village. *Actinopteria* zone exposed 0.1 mile N. of bridge on Dixon Road. Camillus quadrangle. *Ceratiocaris nolli, Eurypterus remipes flintstonensis,* and *Pterygotus* sp. contained in massive, brown, silty dolomite 4 feet 2 inches to 5 feet 1 inch below a porous brown dolomite resembling vesicular lava.

*Locality 15.*—Foundation excavation on the S. side of Bennet Road, 0.3 mile SW. of Warners Road. Camillus quadrangle. A 7-inch shaly dolomite contains abundant specimens of *Waeringopterus cumberlandicus apfeli.* Holotype of the subspecies from this exposure.

*Locality 23.*—Intermittent exposures on hillside between Milton Avenue and U. S. Route 5. Camillus quadrangle. Lowest exposure is in S. side of Milton Avenue at its closest approach to Ninemile Creek, 0.7 mile NE. of Camillus village. *Waeringopterus cumberlandicus apfeli* abundant in 8-inch bed of shaly dolomite 10 feet 9 inches above level of road. About 88 feet 10 inches stratigraphically higher, dolomitic gray shale was temporarily exposed in a house foundation. This shale contains the fauna of the *Camarotoechia* zone, including *Calymene* sp., and is 2 feet 6 inches below a bed of porous gray dolomite resembling vesicular lava.

*Locality 25.*—Road cut exposure on S. side of U. S. Route 5 at the corner of Munroe Drive, 0.6 mile E. of Ninemile Creek. Camillus quadrangle. *Actinopteria* zone fauna including large fragments of *Pterygotus* sp. contained in homogeneous, brown, silty dolomite about 2 feet 2 inches to 3 feet 2 inches below a porous brown dolomite resembling vesicular lava.

*Locality 48.*—Foundation excavation for Skyline Apartments building, NW. corner, James and Lodi Streets, Syracuse. Syracuse West quadrangle. Gray, ripple-marked shale contains *Camarotoechia* zone fauna including *Calymene* sp. 3 feet below a porous gray dolomite resembling vesicular lava.

*Locality 87.*—New York Central railroad cut at Thompson Road and James Street, Syracuse. Syracuse East quadrangle. Conglomerate of shale and dolomite pebbles and quartz sand grains in a dolomite matrix rests on Vernon shale and contains macerated eurypterid fragments. Identifiable fragments of *Pterygotus* sp. and *Waeringopterus cumberlandicus apfeli,* among other fossils.

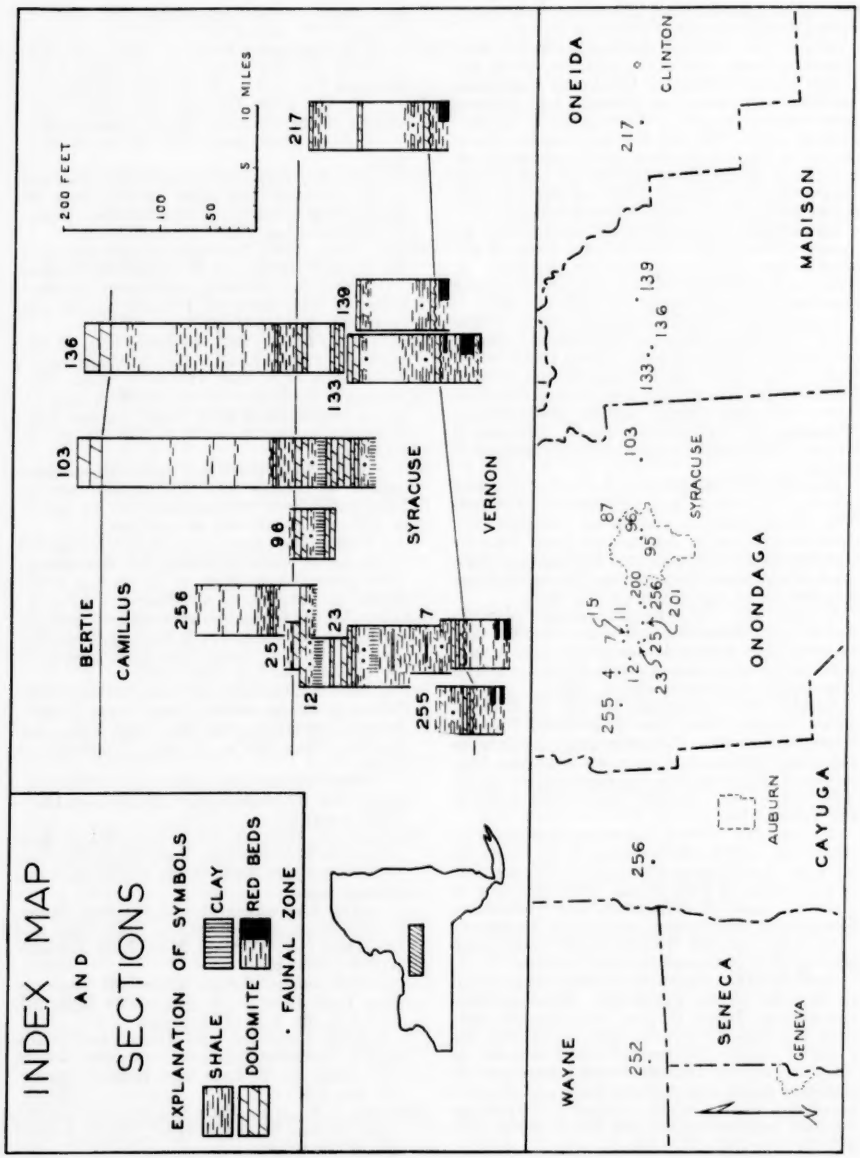
*Locality 95.*—Shale pit between Bruce and Beattie Streets on S. side of Erie Boulevard, Syracuse. Syracuse East quadrangle. Brown, silty dolomite contains *Actinopteria* zone fauna including *Eurypterus remipes flintstonensis* and *Pterygotus* sp. about 2 feet 6 inches above the top of the Upper clay member of the Syracuse formation.

*Locality 96.*—Shale and dolomite quarry on SE. corner of Erie Boulevard and Sealy Road, Syracuse. Syracuse East quadrangle. *Actinopteria* zone fauna with *Pterygotus* sp. in a brown, silty, argillaceous dolomite 2 feet 4 inches above top of the Upper clay member and 3 feet 5 inches below a brown, porous dolomite resembling vesicular lava.

*Locality 103.*—Railroad cut on E. side of Fayetteville-Manlius Center road 0.55 mile SW. of Manlius Center. Syracuse East quadrangle. Talus slab of brown, silty dolomite, evidently from the Middle dolomite member, contains *Eurypterus remipes flintstonensis.*

*Locality 133.*—Section exposed along Canaseraga valley. Canastota quadrangle. Bed of hard, gray dolomite 7 inches thick contains abundant *Waeringopterus cumberlandicus apfeli.* This bed is 14 feet 4 inches above top of the Vernon shale and is exposed in at least four places in the valley about 0.65 mile SE. of Sullivan. About 100 yards W. of road crossing 554 (feet), 1.50 miles SE. of Sullivan, a road cut exposure of gray, fossiliferous shale contains abundant *Camarotoechia* zone fossils with *Carcinosoma* sp. This zone is about 2 feet below a porous, brown dolomite resembling vesicular lava.

*Locality 136.*—Dolomite cliffs at the junction of the two branches of Canaseraga Creek, 0.5 mile SW. of Oak Hill school. Canastota quadrangle. Rare fragments of *Pterygotus* sp. found in talus, possibly from Middle dolomite member.




TEXT-FIG. 2—Columnar sections showing correlation of several Upper Silurian sections described in this article. Columns are drawn directly above their locations on the index map. Shaded portion of New York outline map indicates area of index map.

The section exposed along this valley shows most of the Camillus shale and Bertie formation.

*Locality 139.*—Section exposed in the ravine of Canastota Creek and in the adjacent cut of the Lehigh Valley Railroad at Clockville. Canastota quadrangle. A dense gray dolomite bed 4 inches thick contains abundant *Waeringopterus cumberlandicus apfeli.* This bed is 9 feet 4 inches above the top of the Vernon shale and is exposed in at least three places along the ravine and in one place along the railroad tracks. All exposures are within 350 yards N. of the railroad bridge.

*Locality 200.*—Foundation excavations on SW. corner, Gifford Drive and Myrtes Road, Fairmount. Syracuse West quadrangle. Argillaceous, gray, slabby dolomite 16 feet 5 inches above the *Camarotoechia* zone contains *Ceratiocaris* sp.

*Locality 202.*—Hillside exposure just S. of new street connecting extension of Dunning Drive to extension of Mansfield Drive, three blocks N. of Welsh Drive, Fairmount. Camillus quadrangle. Brown silty dolomite contains *Actinopteria* zone fauna with *Eurypterus remipes flintstonensis, Pterygotus* sp. and *Ceratiocaris nolli.* This zone is 16 feet 1 inch below the top of the Syracuse formation.

*Locality 217.*—Exposures in ravine of small tributary to Deans Creek at school 11, 0.95 mile NW. of triangulation station on Prospect Hill. Clinton quadrangle. Argillaceous gray dolomite contains macerated eurypterid fragments, at least some of which are *Pterygotus* sp. This bed is 9 feet 9 inches above top of the Vernon shale.

*Locality 252.*—Weathered exposure of argillaceous gray dolomite along a dirt road 0.1 mile W. of Creager Bridge. Lyons quadrangle. A talus slab from an elevation of about 450 feet contains *Waeringopterus cumberlandicus apfeli.*

*Locality 255.*—Exposures in road ditch on E. side of Kester Road, just S. of Laird Corners. Jordan quadrangle. Compact, gray, argillaceous dolomite 7 inches thick contains abundant fragments of *Waeringopterus cumberlandicus apfeli.* This bed is about 17 feet 3 inches above top of the Vernon shale.

*Locality 256.*—Small exposures in bank of intermittent stream which crosses N. Y. Route 31, 0.1 mile W. of Conner Road, about 0.5 mile SW. of the center of Port Byron. Exposure is in S. bank of stream, N. of highway, just downstream from bridge. Montezuma quadrangle. Laminated gray shale contains *Waeringopterus cumberlandicus apfeli* at estimated elevation 430 feet.

*Locality 257.*—Exposure in ditch along E. side of Beverly Drive, Fairmount. Syracuse West quadrangle. Brown to gray, very impure dolomite contains *Actinopteria* zone fauna with *Eurypterus remipes flintstonensis* and *Pterygotus* sp. This zone is 3 feet 10 inches below a porous brown dolomite resembling vesicular lava, and about 16 feet below the top of the Syracuse formation (erroneous indicated as 256 just below 200 on text-fig 2)

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JOURNAL OF PALEONTOLOGY, V. 35, NO. 1, P. 65–81, PLS. 17,18, 13 TEXT-FIGS.

# MORPHOLOGY AND ONTOGENY OF *ANKHELASMA*, A NEW MISSISSIPPIAN CORAL GENUS[1]

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ABSTRACT—The new genus *Ankhelasma* is proposed for hapsiphyllid corals found in the Brazer dolomite of northeast Utah and the Hannan limestone of northwest Montana. The known occurrences are in beds considered to be of early Late Mississippian (Meramec) age. *Ankhelasma*, which resembles *Homalophyllites* in external features of the corallum, is distinguished by the conspicuous development of five septal plates and the absence of tabulae.

A large collection of well-preserved silicified specimens of *Ankhelasma typicum*, n. sp., provided an opportunity for detailed study of ontogenetic trends in a population. Changes in six basic morphologic characters related to form and size of the corallum are traced through eleven growth stages distinguished on the number of major septa. The data suggest that curvature of the corallum and flattening of its convex side are due to genetic factors associated with maintaining negatively geotropic growth and stability after toppling from an erect, apically attached position. Progressive obliteration of attachment scars and reduction of apical diameter are attributed to corrosion or abrasion after the corallum became free.

Hypothetical growth curves are derived by plotting two linear characters related to the size of the corallum against time scales based on progressively decreasing growth rates. A logarithmically decreasing growth rate produces the S-shaped curve that characterizes the growth of most simple organisms.

## INTRODUCTION

DURING a recent investigation of upper Paleozoic stratigraphy in the Randolph quadrangle, northeast Utah (Sando, Dutro, and Gere, 1959) corals were used extensively in analyzing stratigraphic relationships of the formations of Mississippian age. A distinctive undescribed genus of small horn corals was particularly helpful in working out the stratigraphy of the Brazer dolomite (Mississippian). One specimen belonging to this genus was subsequently discovered in a collection from the Hannan limestone (Mississippian) in the Saypo quadrangle, northwest Montana. Although most of the specimens from the Brazer are too poorly preserved for detailed biologic analysis, one collection provided an unusually large number of well-preserved silicified specimens probably representing all skeletal growth stages. The purpose of this paper is to describe the general morphology of this new genus and species and to analyze its ontogeny in detail.

I am indebted to Helen Duncan and W. A. Oliver, Jr., for many enlightening discussions concerning various aspects of this study and technical criticism of the manuscript. J. W. Wells, J. T. Dutro, Jr., and A. R. Palmer reviewed the manuscript and contributed valuable suggestions. Thanks are also due M. R. Mudge, who collected the material from northwest Montana. C. E. Fix aided in preliminary preparation of part of the material, computation of part of the quantitative data, photomicrography, and preparation of plates. W. C. Pinckney, Jr., made critical thin sections of the material from northwest Montana. N. W. Shupe produced the photographs of silicified specimens.

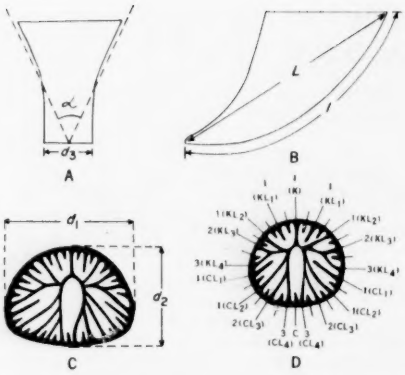
[1] Publication authorized by the Director, U. S. Geological Survey.

## MORPHOLOGIC TERMINOLOGY AND SEPTAL NOTATION

*Morphologic terminology.*—Most of the terms used to describe morphology in the systematic descriptions are defined by Hill (1956, p. 234–251). Quantitative ontogenetic study required use of several rigorously defined measurements and ratios described below and illustrated on Text-fig. 1, A–C.

Length (*L*): the straightline distance from the apex of the corallum to the top of the calice, measured in the cardinal-counter plane. Where the term length is used in systematic descriptions, this is the measurement referred to.

Cardinal length (*l*): the distance from the




TEXT-FIG. 1—Measured characters and septal notation. A, lateral view of young corallum showing apical diameter ($d_3$) and calicular angle ($\alpha$). B, alar view of mature corallum showing length ($L$) and cardinal length ($l$). C, calicular view of neanic corallum showing alar diameter ($d_1$) and cardinal-counter diameter ($d_2$). D, calicular view of neanic corallum showing septal notation: roman numeral one marks first septa to appear; arabic numerals designate successive cycles of major septa; unlabeled lines mark minor septa; C marks cardinal septum; septal notation of Hudson (1936) indicated in parentheses.

apex of the corallum to the top of the calice measured on the convex side along the trace of the cardinal septum.

Alar diameter ($d_1$): the diameter of the calice measured perpendicular to the cardinal-counter plane at or near the top of the calice.

Cardinal-counter diameter ($d_2$): the diameter of the calice measured in the cardinal-counter plane at or near the top of the calice.

Apical diameter ($d_3$): the diameter of the corallum measured at the apex.

Curvature ratio ($L/l$): the ratio of length to cardinal length.

Diameter ratio ($d_2/d_1$): the ratio of cardinal-counter diameter to alar diameter.

Calicular angle ($\alpha$): the angle formed by the sides of the calice measured on the exterior of the corallum in a plane perpendicular to the cardinal-counter plane.

*Septal notation.*—The system of septal notation (text-fig. 1,D) is a modification of that described by Hudson (1936, p. 70). The cardinal half of the corallum is arbitrarily oriented down instead of up as in Hudson's system. Thus, left and right sides of the lumen are the reverse of equivalent parts in the Hudson system. The first septa to appear are labeled with a roman numeral one; these are the counter (K), first counter laterals ($KL_1$), and first cardinal laterals ($CL_1$) of the Hudson system. Arabic numerals designate successive cycles of counter lateral and cardinal lateral septa. Minor septa are marked by short lines without numbers. The cardinal septum (C) is not associated with any particular cycle of major septa and hence is given a separate designation. These modifications of the Hudson notation system provide a clearer representation of the sequence of septal addition in *Ankhelasma*, which departs somewhat from the typical zaphrentid plan.

## SYSTEMATIC DESCRIPTIONS

### Order RUGOSA

### Family HAPSIPHYLLIDAE Grabau, 1928

### Genus ANKHELASMA, n. gen.

*Type species.*—*Ankhelasma typicum*, n. sp.

*Diagnosis.*—Small, solitary, ceratoid or trochoid coralla with a well-developed cardinal fossula on convex side; fossula bounded laterally by fused axial segments of cardinal lateral septa and axially by fused ends of counter and counter lateral septa; septal plan in ephebic stages characterized by retreat of most major septa, leaving only five plates extending from corallum axis to calicular wall in ephebic calice: swollen counter septum, two plates formed by fusion of axial segments of cardinal lateral septa, and two plates formed by fusion of axial segments of counter lateral septa; minor septa present; tabulae absent, open spaces in earlier part of corallum filled with stereoplasm to floor of calyx; dissepiments absent.

*Discussion.*—*Ankhelasma* is placed provisionally in Group II of the family Hapsiphyllidae Grabau as used by Hill (1956, p. 267). Although the family is probably a polyphyletic group, it appears to be a reasonable expression of known morphologic affinities. Features that suggest placement of *Ankhelasma* in the Hapsiphyllidae are the simple, pinnate neanic septal plan, well-developed cardinal fossula, axially joined

major septa, lack of dissepiments, and lack of an axial structure.

*Ankhelasma* is distinguished from all other hapsiphyllid genera by the differential development of major septa at maturity and lack of tabulae. Abnormal development of certain major septa is a characteristic feature of family Polycoeliidae Roemer (*see* Hill, 1956, p. 259–262), but the polycoeliid genera have rhopaloid septa that are semiradially arranged throughout growth and not ordinarily axially fused at maturity. Furthermore, a cardinal fossula is either absent or poorly defined in the polycoeliids.

Exact relationships of *Ankhelasma* to other genera in the Hapsiphyllidae are uncertain. Phylogenetic relationships within the family are obscured by the general morphologic simplicity of the hapsiphyllid genera and the lack of detailed knowledge of their spatial and temporal distribution. However, of all the hapsiphyllid genera, *Ankhelasma* seems most similar to *Homalophyllites* Easton (1944, p. 42). Both genera have a deep, narrow cardinal fossula invariably situated on the convex side of the corallum. In most species of *Homalophyllites*, the convex side of the corallum is flattened at some stage of development; flattening of the convex side of the corallum is a characteristic feature of the type species of *Ankhelasma*. Both genera have moderately strong minor septa which contribute to the formation of a peripheral stereozone at maturity. The known stratigraphic distribution of the two genera supports the suggestion that *Ankhelasma* may have developed from *Homalophyllites*. *Homalophyllites* is restricted to formations of Kinderhook and Osage age, whereas *Ankhelasma* is known only from beds of Meramec age. *Ankhelasma* occurs in dolomites thought to be of penecontemporaneous or early diagenetic replacement origin. This association suggests that the genus may represent an environmental adaptation of the *Homalophyllites* lineage.

ANKHELASMA TYPICUM, n. sp.
Pl. 17, figs. 5–30; pl. 18, figs. 1–10

*Diagnosis.*—Small subcalceoloid *Ankhelasma* with 34 to 42 major septa in ephebic stages.

*Description.*—The corallum is erectly cylindrical in nepionic and early neanic stages but becomes ceratoid or trochoid and convex on the cardinal side in late neanic and ephebic stages (pl. 17, figs. 20–30). In nepionic and early neanic coralla (pl. 18, figs. 8–10), the apex is flat or irregular and exhibits scars of attachment; in later neanic and ephebic specimens, the convex cardinal side is conspicuously flattened and the apex is pointed. The depth of the calice is approximately one-fourth to one-third the length of the corallum in ephebic stages. The epitheca is thin and transversely marked by weak rugae, irregularly spaced 1 to 2 mm. apart, and finer striae. Septal grooves and interseptal ridges are not conspicuous except on abraded specimens. Ephebic coralla range from approximately 15 to 35 mm. in length. The alar and cardinal-counter diameters are approximately equal and measure 8 to 15 mm. in ephebic coralla.

Measurements of the holotype are:

Length: 22.3 mm.
Cardinal length: 23.5 mm.
Alar diameter: 12.5 mm.
Cardinal-counter diameter: 12.0 mm.
Apical diameter: 0.8 mm.
Curvature ratio: 0.95
Diameter ratio: 0.97
Calicular angle: 31 degrees

The cardinal fossula is deep, narrow, expanded axially and constricted near the periphery of the calice. The fossula is invariably situated on the convex side of the mature corallum. The sides of the fossula are composed of fused axial segments of the cardinal lateral septa, which are initially oriented approximately parallel to the cardinal-counter plane but later curve toward the alar septa. The axial part of the fossular wall is composed of the fused axial ends of major septa of the counter quadrants. The septal elements of the fossular wall are augmented by stereoplasm, producing what appears to be a prominent continuous plate bounding the fossula in the mature calice.

Subcalicular features of the mature corallum are not well preserved in the material at hand. However, no evidence of tabulae was seen in longitudinal and transverse sections of silicified specimens. Sections of unsilicified material suggest that the calicular floor was raised by deposition of stereoplasm in the spaces between septa. Evidence

of dissepiments is also lacking. Septal microstructure could not be determined because recrystallization and/or replacement has obliterated all fine details.

The septal plan is strongly pinnate in neanic stages but approaches radiality in ephebic stages. Development of the septal plan is illustrated by the growth series, (pl. 18, figs. 1–7). The initial septa are five in number: counter, two counter laterals and two cardinal laterals (alars). Subsequent major septa are added in groups of four following Kunth's law (1869). The four septa of each cycle appear essentially simultaneously although occasionally addition is accelerated or retarded in the cardinal or counter quadrants; acceleration occurs more commonly in the cardinal quadrants. The cardinal septum, when developed, is short and inconspicuous. It does not appear before the first cycle of four septa is added to the five initial septa; in many specimens, the cardinal septum does not appear until later neanic or early ephebic stages. Minor septa begin to appear when the second cycle of four major septa are added. They are added between the major septa except in the loculi adjacent to the cardinal septum and the loculi on the counter side of the first cardinal lateral (alar) septa. The minor septa are very short in the neanic stages but become longer in the ephebic stages, where they contribute to the formation of a narrow stereozone produced by fusion and thickening of peripheral ends of major and minor septa in the calice. During addition of the third cycle of four major septa, the first counter laterals and first cardinal laterals begin to retreat toward the periphery of the calice. As growth proceeds, the major septa of each successive cycle retreat in the same manner so that in the ephebic calice only the counter and fused axial segments of the counter laterals and cardinal laterals are prominent and extend to the corallum axis.

*Discussion.*—The sequence of septal insertion in *Ankhelasma typicum* seems to represent a departure from the basic zaphrentid plan of Hill (1935, p. 505–506; 1938, p. 33–34). This plan is characterized by insertion of six septa, called protosepta by many writers, including the cardinal, counter, two first cardinal laterals (alars), and two first counter laterals, followed by insertion of other major septa at four points according to Kunth's Law. The first minor septa appear after insertion of the first group of four major septa, most commonly after several cycles of major septa have been inserted. These minor septa arise essentially simultaneously between the major septa. Subsequently, insertion of each major septum is followed closely by insertion of a minor septum in the loculus on the counter side of the newly formed major septum.

Variations of this basic plan mainly pertain to the sequence in which the first six major septa are developed. The first six septa are commonly developed in three steps, as described by Curruthers (1906) in *Zaphrentites phillipsi* (Milne-Edwards and Haime): (1) formation of an axial septum that subsequently becomes cardinal and counter septa, (2) formation of two septa, one on each side of the cardinal end of the axial septum, which shift toward the counter side of the corallum and form the first cardinal laterals (alars), and (3) formation of two septa, one on each side of the counter end of the axial septum, which move toward the cardinal side and form the first counter laterals. In some genera, this early development is accelerated so that four or six initial major septa appear simultaneously. Genera belonging to the subfamilies Plerophyllinae and Tachylasmatinae of family Polycoeliidae are characterized by simultaneous appearance of five initial septa: cardinal, two first cardinal laterals (alars), and two first counter laterals. The counter septum does not appear until after insertion of the first group of four later major septa.

In *Ankhelasma typicum*, the youngest individuals studied are represented by simple cup-shaped to cylindrical coralla 1.1 to 2.2 mm. long and 1.5 to 1.9 mm. in diameter (pl. 17, figs. 9,20; pl. 18, fig. 1). Most of these coralla show no evidence of septa; in a few specimens, faint ridges on the floor of the calice suggest early septal formation. The next stage that can be recognized shows five well-developed major septa: counter, two first cardinal laterals (alars), and two first counter laterals (pl. 18, fig. 2). The coralla are 1.6 to 3.3 mm. long and 1.4 to 2.3 mm. in diameter (alar diameter equals cardinal-counter diameter). The evidence suggests essentially simultaneous formation

of five initial major septa. Insertion of subsequent major septa follows the characteristic zaphrentid plan described above. The cardinal septum does not appear until after insertion of the first cycle of four major septa and always remains very short. Insertion of minor septa follows the characteristic zaphrentid pattern. Thus, the sequence of early septal development in *Ankhelasma* appears to represent an acceleration of five of the six "protosepta" and retardation of the cardinal septum, followed by essentially normal zaphrentid insertion. Presence of an initial five-septum stage suggests similarity to the plerophyllinids and tachylasmatinids, but in these groups, the counter septum is retarded instead of the cardinal.

The phylogenetic significance of variation in the plan of septal insertion has not been completely evaluated. Early ontogeny has been investigated in relatively few rugose corals. Taxa included by Hill (1935, p. 506; 1938, p. 34) in the group characterized by zaphrentid insertion are placed in at least five different families in the most recent classification of the Rugosa (Hill, 1956). Detailed analysis of the significance of early septal development in *Ankhelasma* is best deferred until more is known about septal development in other rugose genera.

*Occurrence and faunal association.*—The type material was collected from the upper part of the Brazer dolomite at ten localities in the Crawford Mountains, Randolph quadrangle, Rich County, northeast Utah. These occurrences appear to be of Late Mississippian (Meramec) age. The stratigraphy of the Brazer dolomite is described in detail in a previous paper (Sando, Dutro, and Gere, 1959). Pertinent locality data are given below.

USGS Locality 486-PC: NW¼ NW¼ sec. 29, T. 11 N., R. 8 E. Collected by G. H. Girty and G. B. Richardson in 1912. Member 3, exact stratigraphic position within the member unknown. 3 specimens preserved as molds and casts in chert associated with *Syringopora* 2 spp., *Schuchertella* sp., *Composita* sp., and indeterminate dictyoclostid and other productoid brachiopods.

USGS Locality 16906-PC: SE¼ NW¼ sec. 20, T. 11 N., R. 8 E. (Brazer Canyon). Type section of Brazer dolomite. Member 3, 146 feet above base of member. 2 poorly preserved specimens in dolomite matrix associated with *Canadiphyllum?* sp. and an indeterminate horn coral.

USGS Locality 16907-PC: SE¼ NW¼ sec. 20, T. 11 N., R. 8 E. (Brazer Canyon). Type section of Brazer dolomite. Member 3, 158 feet above base of member. 5 poorly preserved specimens in dolomite matrix associated with *Canadiphyllum?* sp., *Spirifer* aff. *S. leidyi* Norwood and Pratten, and *Spirifer* sp.

USGS Locality 16908-PC: SE¼ NW¼ sec. 20, T. 11 N., R. 8 E. (Brazer Canyon). Type section of Brazer dolomite. Member 3, float from 135 to 166 feet above base of member. 11 poorly preserved specimens in dolomite matrix associated with *Canadiphyllum?* sp. and a large dissepimented coral which may possibly be a *Faberophyllum.*

USGS Locality 16936-PC: Center sec. 17, T. 11 N., R. 8 E. (Emma Canyon). Member 3, 158 feet above base of member. Approximately 30 specimens preserved as molds and casts in chert associated with *Spirifer* aff. *S. leidyi* Norwood and Pratten, and indeterminate orthotetid and productoid brachiopods.

USGS Locality 16938-PC: Center sec. 17, T. 11 N., R. 8 E. (Emma Canyon). Member 3, 185 feet above base of member. 6 poorly preserved specimens in dolomite matrix associated with *Canadiphyllum?* sp. and *Timania?* sp.

USGS Locality 16939-PC: Center sec. 17, T. 11 N., R. 8 E. (Emma Canyon). Member 3, 145 feet above base of member. 3 poorly preserved specimens in dolomite matrix associated with *Canadiphyllum?* sp. and *Syringopora?* sp.

USGS Locality 17717-PC: NW¼ NE¼ sec. 31, T. 11 N., R. 8 E. Member 3, exact stratigraphic position within the member unknown. Several hundred poorly preserved silicified specimens etched from dolomite matrix; associated with *Syringopora* sp.

USGS Locality 17722-PC: SE¼ NW¼ sec. 31, T. 11 N., R. 8 E. Member 3, 123 to 133 feet above base of member. 285 well preserved silicified specimens and several hundred poorly preserved silicified specimens etched from dolomite matrix associated with *Canadiphyllum?* sp. and a large indeterminate orthotetid brachiopod.

USGS Locality 18074-PC: NW¼ NW¼

sec. 6, T. 10 N., R. 8 E. Member 3, exact stratigraphic position within the member unknown. Approximately 50 poorly preserved specimens in dolomite matrix.

*Types.*—Holotype, USNM 120201; figured paratypes, USNM 120202–120217; unfigured paratypes, USNM 120218–120227.

ANKHELASMA sp. cf. A. TYPICUM
Pl. 17, figs. 1–4; pl. 18, fig. 11

*Description.*—One well preserved specimen in dolomite matrix from the Hannan limestone of northwest Montana was discovered in a random slice through a rock sample; part of the specimen was destroyed in the process. External features could not be seen. The length of the corallum was not measured before preparation of thin sections and cannot now be determined. Position of the cardinal fossula on the convex side of the corallum was determined during sectioning. All that remains of the specimen is five transverse thin sections illustrating neanic and ephebic stages.

The earliest section obtained (pl. 17, fig. 1) exhibits 18 pinnately arranged major septa, suggesting a neanic stage characterized by addition of the third cycle of four major septa. Addition of major septa of the last cycle appears to have been slightly retarded in the left counter and right cardinal quadrants. The cardinal septum is short and lies in a well-defined stereoplasm-filled fossula. The fossular wall in the cardinal quadrants is composed of axial segments of the cardinal lateral septa. Each of these septa at first grows axially approximately parallel to the cardinal-counter plane, but as growth proceeds, the point of origin moves around the periphery toward the counter septum so that the septum curves at a progressively increasing angle to the cardinal-counter plane. The axial part of the fossular wall appears to be made up largely of axial segments of the first counter lateral septa, which initially are oriented at a slight angle to the alar plane, then curve progressively toward the counter septum. The counter septum does not appear to form a significant part of the wall; it seems to be fused to the axial ends of the first counter lateral septa. Twelve short minor septa can be seen at the periphery of the corallum. All loculi are filled with stereoplasm. The corallum is nearly circular in cross section but shows slight flattening on the cardinal side. The alar diameter is 2.6 mm. and the cardinal-counter diameter is 2.2 mm.

A section higher in the corallum (pl. 17, fig. 2) exhibits 25 major septa, suggesting a neanic stage characterized by addition of the fifth cycle of four major septa. Addition of major septa of the last cycle appears to have been retarded again in the left counter and right cardinal quadrants. The right cardinal quadrant contains one less major septum than the normal complement for this stage. Major septa of the first cycle of four have retreated half way to the periphery of the corallum. There are 20 short minor septa. The aborted cardinal septum lies in a well-defined stereoplasm-filled fossula as before. The components of the fossular wall are easily distinguished in the thin section. As in the previous stage, the sides of this wall are composed of axial segments of the cardinal lateral septa. The axial part of the fossular wall is now composed of axial segments of several cycles of counter lateral septa. Loculi are completely filled with stereoplasm. The corallum is strongly ovate in cross section owing to flattening of the cardinal side. The alar diameter is 5.8 mm., and the cardinal-counter diameter is 4.7mm.

A still higher section (pl. 17, fig. 3) exhibits 7 major septa in the left counter quadrant and 8 major septa in the right counter quadrant; septal complements of the cardinal quadrants cannot be determined owing to destruction of most of these areas. Inasmuch as the left counter quadrant is retarded in earlier stages, the number of septa in the right counter quadrant probably represents the normal septal complement. Hence, this section probably represents an ephebic stage characterized by addition of the seventh cycle of four major septa, which should produce a normal total of 34 major septa. Five thick plates extend from the periphery to the axis of the corallum, where their axial edges are joined: one plate in the position of the counter septum, two plates in the alar plane, dividing the lumen into cardinal and counter halves, and two plates approximately parallel to the cardinal-

counter plane forming the sides of the fossula. The traces of these plates on the plane of section are mutually continuous dark lines showing no trace of their composite origin. Their relative positions suggest that the counter plate is merely a thickened counter septum, the two alar plates arose from fused axial segments of counter lateral septa, and the two cardinal lateral plates arose from fused axial segments of the cardinal lateral septa. The major septa do not reach the axis and are buried in stereoplasm, which fills all open spaces in the interior of the corallum. An incipient peripheral stereozone is formed by the minor septa and radially disposed peripheral segments of the major septa. The corallum is approximately circular in cross section. The alar diameter is 8.9 mm.

The highest section seen (pl. 17, fig. 4) is slightly above the floor of the calice. Eight major septa are present in each of the counter quadrants; this septal complement suggests that the individual had not advanced beyond the ephebic stage characterized by insertion of the seventh cycle of four major septa. The counter plate reaches only half way to the center of the corallum; alar and cardinal lateral plates reach the axial region, but the axial part of the fossular wall does not attain this level. The major septa are short and terminate axially in the open calice. Minor septa are almost as long as the major septa. Radially arranged thickened minor septa and peripheral segments of major septa form a stereozone that occupies approximately the outer third the radius of the corallum. The corallum is nearly circular in cross section and has an alar diameter of 10.2 mm.

Traces of tabulae are not visible in any of the sections studied. Dilation of septa and filling of loculi with stereoplasm in early parts of the corallum commonly obscures tabulation in some hapsiphyllid species. However, tabulation is almost always visible in ephebic sections just below the floor of the calice. If tabulae were present in *Ankhelasm* cf. *A. typicum*, their traces should be visible in the ephebic section studied (pl. 17, fig. 3). It is concluded that tabulae are not present in this species.

The thin sections show vestiges of original septal microstructure, although details are obscured by recrystallization and/or replacement. The septa appear to be composed of fibers arranged approximately at right angles to the septal plane (pl. 18, fig. 11). Sutherland (1958, p. 49–50) noted five types of septal microstructure in species he referred to the family Hapsiphyllidae. The microstructure of *Ankhelasma* cf. *A. typicum* is similar to that of Sutherland's type D (fibro-lamellar skeleton in which the septa are composed of fibre fascicles not grouped into trabeculae and arranged at right angles to the plane of the septa) and type E (fibre fascicles are arranged at right angles to the plane of the septa and may be grouped into trabeculae). Closer comparisons cannot be made until better material is available.

*Discussion.*—The morphology of *Ankhelasma* cf. *A. typicum* is similar to that of *A. typicum* in all comparable details. Values of alar diameter, cardinal-counter diameter, and diameter ratio in *Ankhelasma* cf. *A. typicum* fall within the limits of variation of these features in paratypes of *A. typicum* in each comparable ontogenetic stage based on septal number. Development of the septal plan and other internal features appears to be essentially the same in both taxa. The two taxa probably cannot be distinguished on morphological criteria. However, one specimen does not provide an adequate sample of a population, and the population represented by *Ankhelasma* cf. *A. typicum* might differ greatly from that of *A. typicum*. The specimen of *Ankhelasma* cf. *A. typicum* was collected in northwest Montana, approximately 400 miles from the type locality of *A. typicum*. Both localities occur in rocks thought to be of Late Mississippian (Meramec) age, but more precise correlation cannot be established at this time. Until more information is available, identity of the species from the Hannan limestone cannot be confidently determined. The Hannan specimen is therefore excluded from the type lot of *A. typicum* and described separately.

*Occurrence.*—The material was collected by M. R. Mudge from the Hannan limestone, in the Saypo quadrangle (30 minute), Teton County, northwest Montana at USGS Locality 18005-PC: south end of Hannan Gulch, lat. 47° 37′ N., long.

112° 43′ 30″ W. (type section of Hannan limestone). The collection is from a dolomite bed 1250 feet above the Devonian-Mississippian boundary and 100 feet below the top of the formation.

In addition to *Ankhelasma* cf. *A. typicum*, the collection contains *Zaphrentites?* sp. and indeterminate horn corals. The locality occurs within a faunal unit of Meramec age. Fossils collected from this unit in the Saypo quadrangle include *Syringopora surcularia* Girty, *Lithostrotion* (*Siphonodendron*) aff. *L. arundineum* Etheridge, *Thysanophyllum* sp., *Diphyphyllum* sp., *Vesiculophyllum?* sp., *Enygmophyllum* sp., *Faberophyllum* sp., *Dichotrypa* sp., *Perditocardinia* cf. *P. dubia* (Hall), *Streptorhynchus* sp., and *Cleiothyridina* sp.

*Figure specimen.*—USNM 120228.

## ONTOGENY

*Nature of sample.*—This ontogenetic study is based on a suite of 285 well preserved silicified specimens of *Ankhelasma typicum* collected from the Brazer dolomite at USGS locality 17722-PC. The material was etched from a block of dolomite approximately 6 inches by 3 inches by 3 inches collected from a layer of corals a few inches thick. The dolomite matrix is dark brown, fine-grained, and contains small echinoid and crinoid fragments in addition to corals. The silicified residue left by etching contained hundreds of coral skeletons. This material was carefully examined and all specimens complete enough for measurement were segregated to form the sample for study.

The corals were randomly oriented in the rock (pl. 17, fig. 5). Probably few, if any, specimens were in normal growth position. Many specimens are strongly abraded. These facts indicate that the deposit consisted of a mechanical accumulation of skeletons on the sea floor. The poor sorting and generally good preservation suggest that the skeletons were not transported far. The lack of appreciable morphologic variation and lack of evidence of significant transport suggest that the assemblage represents a genetically homogeneous population living in a relatively small area. Probably several generations of animals are represented in the sample.

*Procedure.*—Preliminary examination of the sample indicated that the number of major septa is the best approximation of a criterion of absolute age of an individual. Addition of major septa follows a relatively orderly pattern with few exceptions; simultaneous formation of five initial septa is followed by insertion of major septa in cycles of four. Although insertion is continuous from one septal cycle to the next, the pattern of addition lends itself well to objective segregation of individuals into growth stages. The number of major septa can be counted accurately on a large number of specimens. Other characters, such as length and width of the corallum, are more variable and difficult to measure.

Eleven growth stages are recognized in

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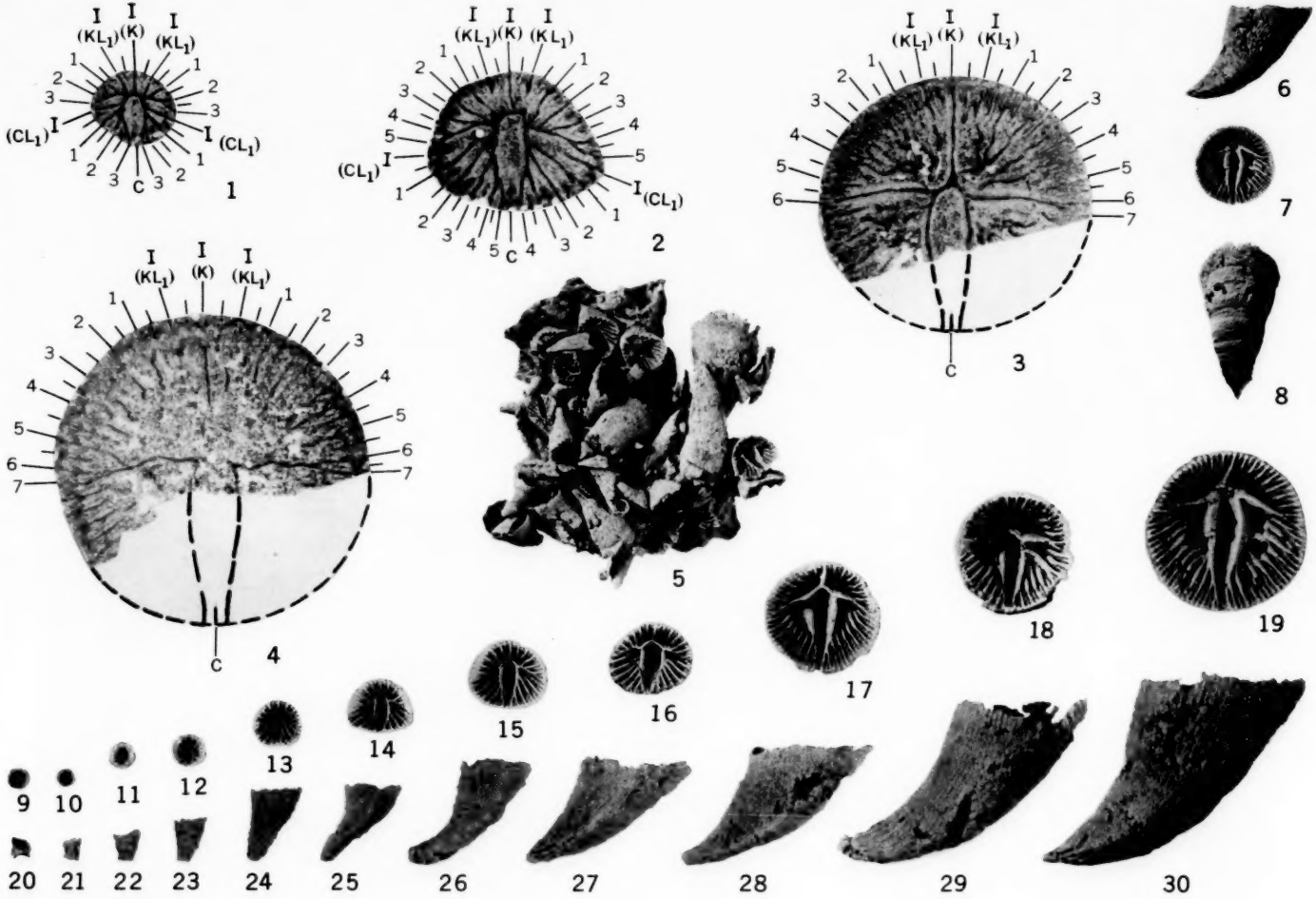
EXPLANATION OF PLATE 17

All specimens from Brazer dolomite, USGS locality 17722-PC, Randolph quadrangle, Rich County, Utah, unless otherwise indicated.

FIGS. *1–4*—*Ankhelasma* sp. cf. *A. typicum*. Serial sections, ×5, of a specimen from the Hannan limestone, Saypo quadrangle, Teton County, Montana, USNM 120228, USGS locality 18005-PC.

*5–30*—*Ankhelasma typicum*, n. sp. *5*, silicified specimens in matrix, ×1, USNM 120202. *6–8*, alar, calicular, and cardinal views respectively of holotype, ×1, USNM 120201. *9–30*, etched specimens illustrating eleven growth stages described in text; *9–18*, calicular views of paratypes, ×2, USNM 120203–120212, respectively; *19*, calicular view of holotype, ×2, USNM 120201; *20–29*, alar views of paratypes, ×2, USNM 120203–120206, 12013, 120208, 120209, 120214, 120211, 120212, respectively; *30*, alar view of holotype, ×2, USNM 120201.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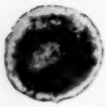

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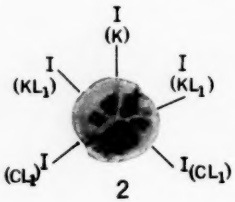


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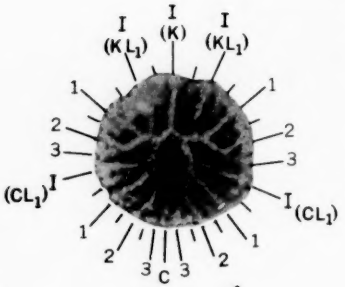


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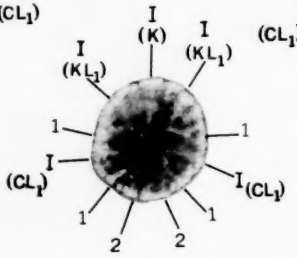


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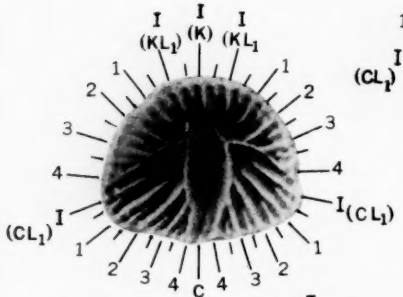


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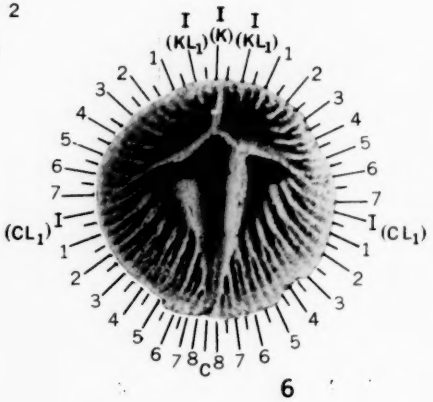


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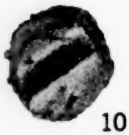

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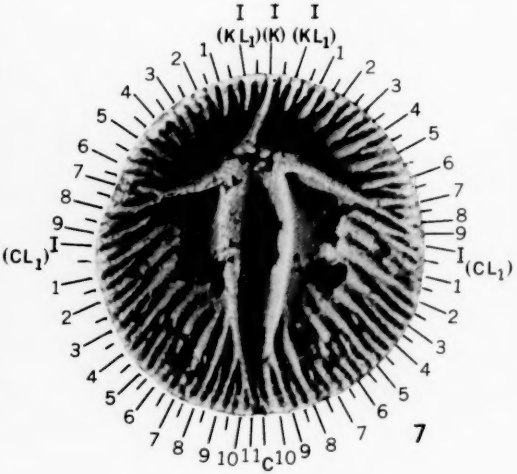
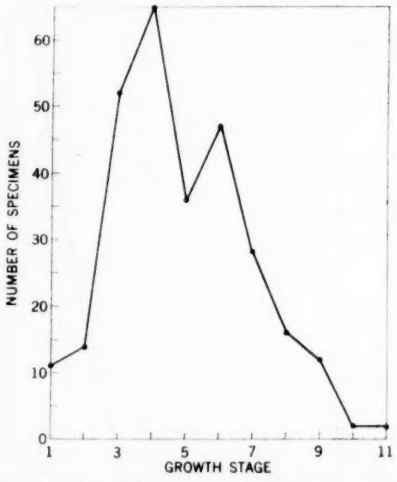



7

the ontogenetic sequence (pl. 17, figs. 9–30). Stage 1 is characterized by absence of septa (pl. 18, fig. 1). Stage 2 exhibits five major septa (counter, two first counter laterals, and two first cardinal laterals) (pl. 18, fig. 2). In stage 3, the first cycle of four major septa are added (pl. 18, fig. 3). Each succeeding stage is characterized by insertion of four major septa up to a maximum of 42 (including the cardinal septum which is not associated with any particular cycle) in stage 11 (pl. 18, fig. 7). Segregation of the sample into growth stages produced the frequency distribution shown in text-fig. 2.

Close examination of the segregated sample revealed certain interesting morphologic trends during growth. These empirically determined ontogenetic patterns were then tested by measurements of the morphologic characters involved. Mean values were calculated for each growth stage and curves plotted showing ontogenetic changes (text-figs. 3–10). Plotting of mean values based on many specimens representing each growth stage provides a more realistic representation of ontogenetic trends of the population than data based on only one or a few specimens.

*Ontogenetic patterns.*—Text-figs. 3–6 show the curves for ontogenetic changes in length ($L$), cardinal length ($l$), alar diameter ($d_1$), and cardinal-counter diameter ($d_2$). These linear characters are well correlated and have similar curves. In each case the slope of the curve shows a maximum change near stage 5.




TEXT-FIG. 2—Frequency distribution of growth stages in selected samples of *Ankhelasma typicum*.

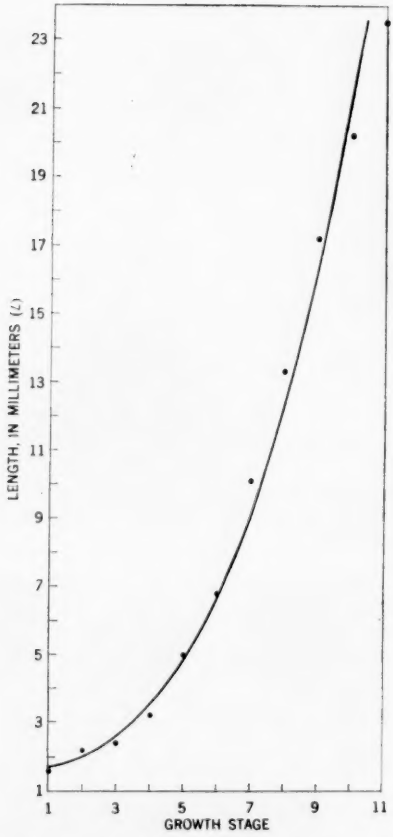
The diameter ratio ($d_2/d_1$) is an expression of the cross-sectional shape of the calice. The curve for this ratio (text-fig. 7) indicates that the calice is circular in stages 1 and 2, but departs from circularity towards stage 6, then approaches it again in stages 10 and 11. This pattern results from flattening of the cardinal side of the corallum, which is expressed in shortening of the cardinal-counter diameter ($d_2$) relative to the alar diameter ($d_1$) in the intermediate

EXPLANATION OF PLATE 18

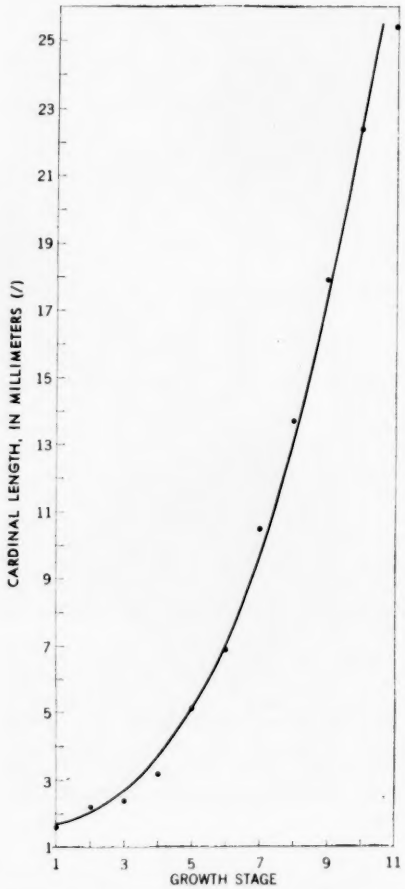
All specimens from Brazer dolomite, USGS locality 17722-PC, Randolph quadrangle, Rich County, Utah, unless otherwise indicated.

FIGS. *1–10—Ankhelasma typicum*, n. sp. *1–4*, calicular views of paratypes illustrating growth stages 1–4, ×8, USNM 120203–120206, respectively; *5*, calicular view of paratype, growth stage 6, ×6, USNM 120208; *6*, calicular view of paratype, growth stage 9, ×4, USNM 120211; *7*, calicular view of holotype, growth stage 11, ×4, USNM 120201; *8–10*, apical views of young paratypes showing attachment scars, ×8, USNM 120215–120217, respectively.

*11—Ankhelasma* cf. *A. typicum*. Septal microstructure, ×75, polarized light, crossed nicols; *a*, dark line marking trace of medial septal plane; *b*, edges of septum; USNM 120228, from Hannan limestone Saypo quadrangle, Teton County, Montana, USGS locality 18005-PC.




TEXT-FIG. 3—Ontogenetic variation of length ($L$) in selected sample of *Ankhelasma typicum*. Points represent mean values of 11, 13, 40, 61, 36, 43, 27, 14, 10, 2, and 2 measurements on specimens of stages 1 through 11, respectively. Curve fitted visually.



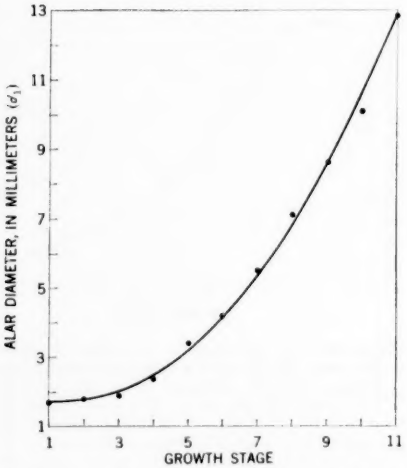

TEXT-FIG. 4—Ontogenetic variation of cardinal length ($l$) in selected sample of *Ankhelasma typicum*. Points represent mean values of 11, 13, 40, 61, 35, 43, 27, 14, 10, 2, and 2 measurements on specimens of stages 1 through 11, respectively. Values for stages 1 through 4 taken from measurements of $L$ because $l$ is approximately equal to $L$ in these stages. Curve fitted visually.

growth stages. The maximum departure from circularity occurs in stage 6.

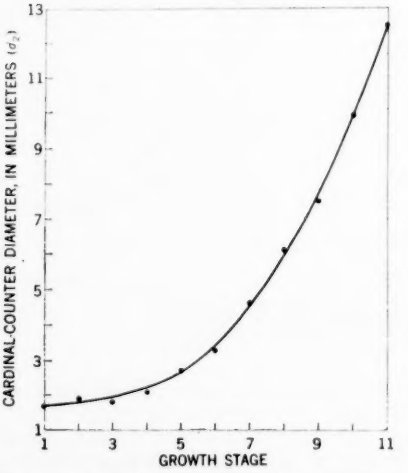
The curvature ratio ($L/l$) is an expression of the amount of curvature of the corallum in the cardinal-counter plane. The corallum is essentially an erect cylinder or cone in stages 1 through 5, but becomes increasingly curved between stages 5 and 11 (text-fig. 8).

The calicular angle ($\alpha$) expresses the angular divergence of the sides of the calice in a plane perpendicular to the cardinal-counter plane. This angle increases to a maximum between stages 5 and 6, then declines until stage 9, after which it increases again (text-fig. 9).

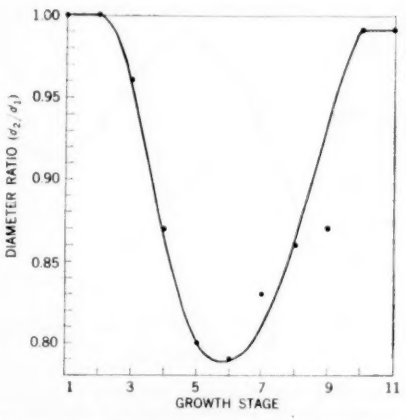
*Inferred ontogenetic changes in growth*




TEXT-FIG. 5—Ontogenetic variation of alar diameter ($d_1$) in selected sample of *Ankhelasma typicum*. Points represent mean values of 11, 11, 47, 59, 33, 42, 28, 16, 12, 2, and 2 measurements on specimens of stages 1 through 11, respectively. Curve fitted visually.

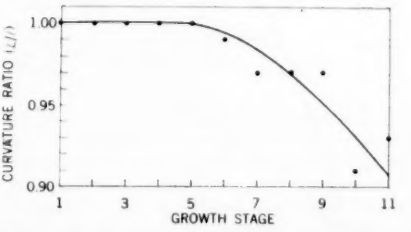



TEXT-FIG. 6—Ontogenetic variation of cardinal-counter diameter ($d_2$) in selected sample of *Ankhelasma typicum*. Points represent mean values of 11, 10, 47, 60, 35, 45, 27, 16, 12, 2, and 2 measurements on specimens of stages 1 through 11 respectively. Value for stage 1 taken from measurements of $d_1$ because $d_1$ is approximately equal to $d_2$ in this stage. Curve fitted visually.

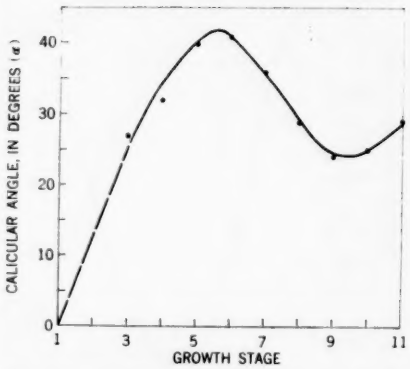



TEXT-FIG. 7—Ontogenetic variation of diameter ratio ($d_2/d_1$) in selected sample of *Ankhelasma typicum*. Points represent mean values of 11, 9, 45, 53, 33, 42, 27, 16, 12, 2, and 2 measurements on specimens of stages 1 through 11, respectively. Curve fitted visually.

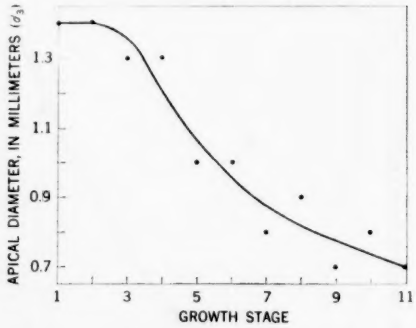
*habit.*—Wells (1937, p. 15–16) has reviewed the principal theories concerning morphogenesis of the simple curved rugose corallum and concluded that Bernard's (1904) hypothesis most nearly explains the origin of these curved forms. Bernard (1904, p. 10) suggested that the young polyp inhabited a conical cup with a flat base that rested on the substrate. As the polyp grew and the cup expanded upward, the skeleton became increasingly unstable. Eventually, the corallum broke off from the substrate and lay on



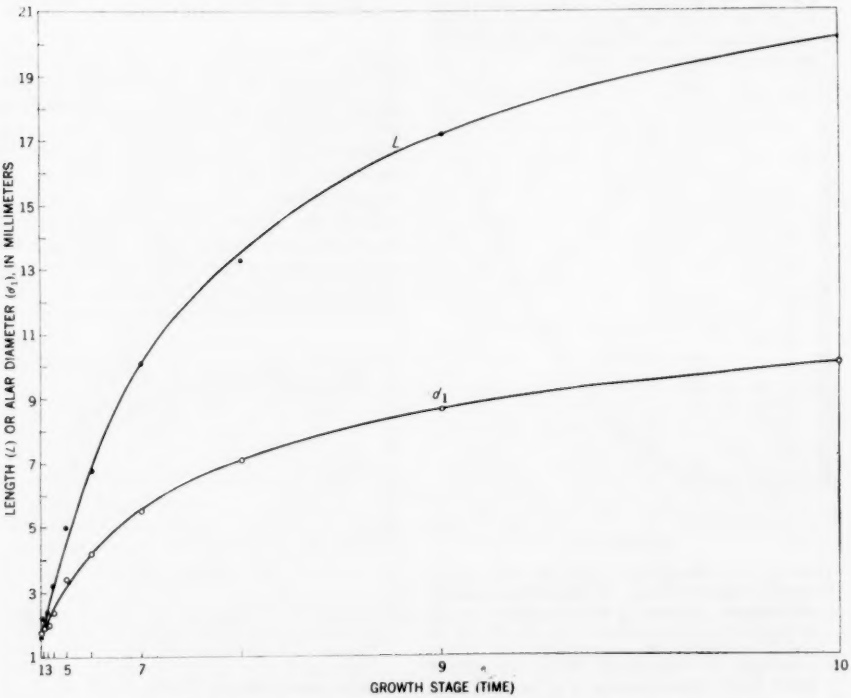

TEXT-FIG. 8—Ontogenetic variation of curvature ratio ($L/l$) in selected sample of *Ankhelasma typicum*. $L$ is approximately equal to $l$ in stages 1 through 4. In stages 5 through 11, points represent mean values of 35, 43, 27, 14, 10, 2, and 2 measurements, respectively. Curve fitted visually.



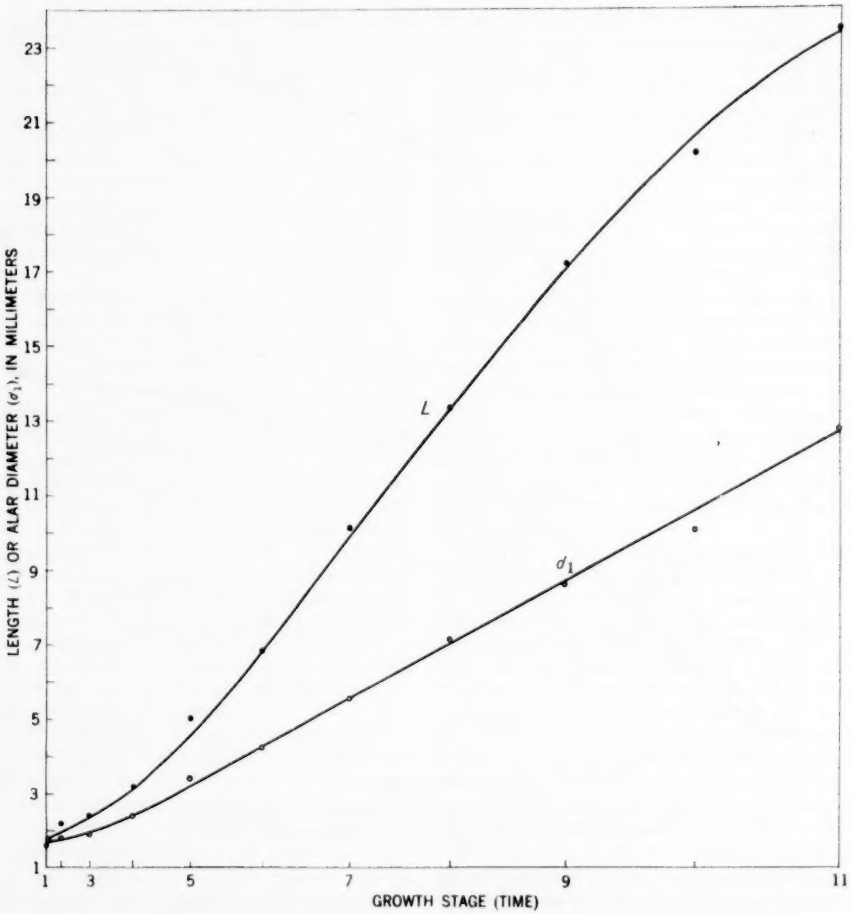

TEXT-FIG. *9*—Ontogenetic variation of calicular angle ($\alpha$) in selected sample of *Ankhelasma typicum*. In stages 3 through 11, points represent values of 31, 50, 33, 44, 27, 16, 12, 2, and 2 measurements, respectively. Curve fitted visually; curve extrapolated for stages 1 and 2.




TEXT-FIG. *10*—Ontogenetic variation of apical diameter ($d_3$) in selected sample of *Ankhelasma typicum*. Points represent mean values of 10, 13, 45, 60, 32, 38, 24, 11, 9, 2, and 2 measurements on specimens of stages 1 through 11, respectively. Curve fitted visually.

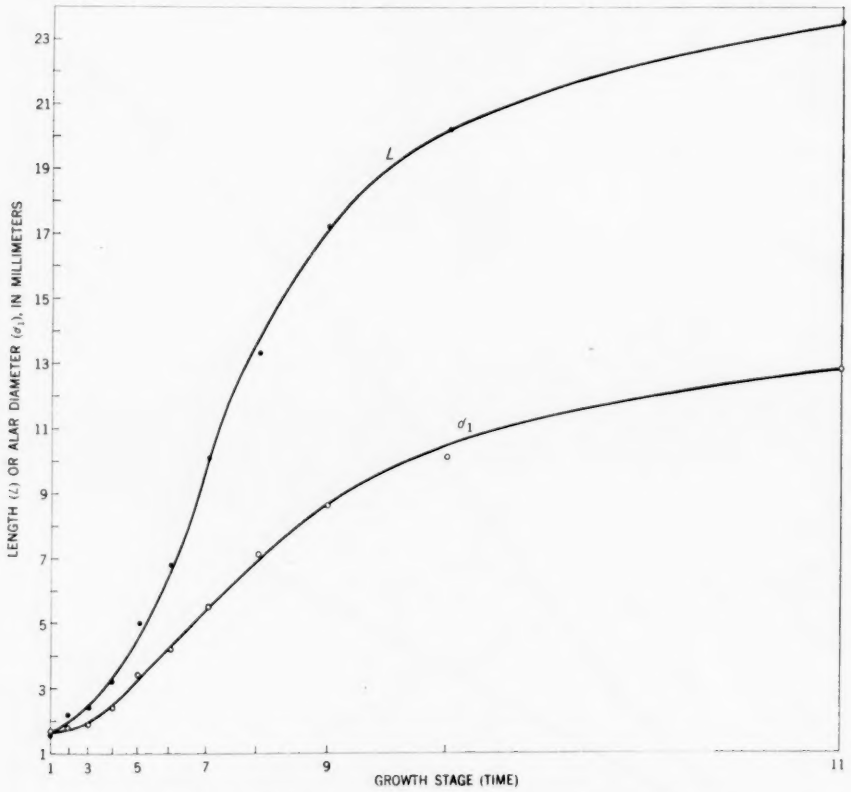



TEXT-FIG. *11*—Length ($L$) and alar diameter ($d_1$) plotted against time scale based on geometrically decreasing growth rate.




TEXT-FIG. *12*—Length ($L$) and alar diameter ($d_1$) plotted against time scale based on arithmetically decreasing growth rate.

its side. The polyp then re-attached itself to the substrate and attempted to regain its previous upright position, thus producing a curved corallum. Wells (1937, p. 16) observed a similar change in growth form in species of the living scleractinian *Caryophyllia:* "Some species, such as *Caryophyllia communis* (Seguenza), are often free, either having been attached to some very small loose fragment or having broken off at their point of attachment which is usually less than 2 mm. across, and lying on their sides on the bottom, sinking slightly into it if it be soft enough. The calice of such forms, in common with that of all living simple corals, is directed upwards, its plane horizontal or tending to be so. When the coral topples over the polyp grows upward away from its previous direction, trying to realign the calice. Continued growth adds more weight to the calicular end, unbalancing the corallum which rolls on its (now) basal side, gradually lifting the small tip away from the substratum." Oliver (1958, p. 817–818) has




TEXT-FIG. *13*—Length ($L$) and alar diameter ($d_1$) plotted against time scale based on logarithmically decreasing growth rate.

discussed the significance of flattening of the side of the corallum in curved-conical rugose corals. He concluded that in some forms, such as *Aemulophyllum*, flattening is closely related to the living position of the coral, whereas in others, such as *Homalophyllum*, flattening is seemingly unrelated to environmental conditions.

Curvature and flattening of the corallum are clearly a function of individual variation in many rugose coral species. Wells' classic study of *Heliophyllum halli* (1937) is a good example of the tremendous variation in form of the corallum that characterizes some rugose corals. In most cases, variation in curvature is directly related to maintenance of a position conducive to optimum growth of the animal. Other rugose coral species show such little variation in form that curvature and flattening in these groups are probably due to genetic factors. Curved and flattened coralla developed as genetic trends in several unrelated rugose lineages, but these trends presumably originated as simple individual variations.

Growth patterns in *Ankhelasma typicum* seem to represent genetic trends that were developed through environmental adaptation. Curvature and flattening and broadening of the convex side of the corallum are regarded as genetic instruments for maintaining negatively geotropic growth and stability after toppling from an erect, apically attached position. Most of the individuals

representing the first four growth stages have flat or indented apices (pl. 18, figs. 8–10), indicating attachment to hard objects on the sea floor. The nature of the scars suggests that many of these were attached to the skeletons of other animals such as echinoderms and brachiopods. Evidence of attachment is less common in the individuals representing stages 5 and 6 and is rare in stage 7. None of the specimens representing stages 8 through 11 show evidence of attachment.

Obliteration of attachment scars and reduction in apical diameter (text-fig. 10) may be related to the destructive influences of other organisms acting on the corallum while it was still occupied by the living polyp. D. F. Squires (oral communication, 1960) has observed a similar modification of the apex in the living *Flabellum*. According to Squires, some species of *Flabellum* assume a recumbent growth position on the sea floor after an early period of attachment. Associated sponges, hydrozoans, bryozoans, and other organisms produce conditions that result in corrosion of the apical end of the corallum. Removal of material by boring and biting organisms may also contribute to the modification of the apex both before and after the change from an attached to a recumbent growth position.

The rarity of evidence of attachment beyond stage 6 indicates that a change from attached to free growth took place, on the average, before or during stage 6. According to the theories of Bernard and Wells, the point at which the corallum begins to curve should also mark the change in growth habit. Variation in the curvature ratio (text-fig. 8) suggests that this took place on the average in stage 5 or 6. The fact that the curves for length, cardinal length, cardinal-counter diameter, alar diameter, diameter ratio, and calicular angle (text-figs. 3–7,9) all show a turning point during approximately the same period in the developmental sequence supports this interpretation.

The production of a flat area on the convex side of the corallum seems to have been a response to the need for stability when the corallum rested on its side on the substrate. This flattening is reflected in the progressive decrease of the diameter ratio (text-fig. 7) and increase of the calicular angle (text-fig. 9) toward stage 5 or 6. Contrary to Bernard's suggestion that the coral reattached itself after falling on its side, no evidence of such attachment has been seen in *Ankhelasma*. Probably the coral attained stability by resting on its flattened side and sinking slightly into a soft bottom, its apical end weighted down by stereoplasm. The curves for diameter ratio and calicular angle indicate that the flattened area was gradually built up to a maximum in stages 5 and 6, after which the corallum gradually returned to its previous circular cross-section. The fact that flattening began before the change from attached to free growth indicates that this feature was genetically controlled and not a simple individual response to the environment. A return to optimum stability in stages 9 through 11 is suggested by the similarity of the diameter ratio and calicular angle curves in these stages to the curves in the early, attached stages (text-figs. 7 and 9).

*Inferred growth curve.*—Studies of living scleractinian corals indicate that growth of the skeleton is governed by many factors, whose relative effects are not well known. Stephenson and Stephenson (1933, p. 174–178) list the following factors influencing coral growth: (1) inconstancy of growth rate associated with no known cause, (2) environment, (3) size (age), (4) individual variation, and (5) form and internal structure of a colony. Growth data on recent corals are not easily applied to analyses of Paleozoic solitary corals because: (1) the recent corals may not be closely related phylogenetically to the Paleozoic corals, (2) most of the data on recent corals are based on studies of colonial forms which now form a greater proportion of the coral fauna than they did during the Paleozoic, and (3) the ecology of recent corals whose growth has been studied is probably quite different from that of the Paleozoic solitary corals. In spite of these limiting factors, the ancient and recent corals are probably similar enough to warrant broad comparisons of some aspects of their growth.

The problem at hand is to draw some inferences concerning skeletal growth in *Ankhelasma typicum*. It has been assumed that stages based on the number of major septa approximate points on the true growth

curve of this coral. In order to arrive at an approximation of the growth curve, information concerning the growth rate is also needed. One cannot hope to reconstruct an absolute growth curve for the species, but only a curve showing approximate relative growth from one ontogenetic stage of the skeleton to another.

Some of Stephenson and Stephenson's growth factors may be eliminated from consideration in the present study. Form and internal structure of a colony are factors that do not affect the growth of a solitary coral. If comparable factors are operable on solitary corals, they would be essentially constant in the sample of *Ankhelasma typicum*. Environmental factors are assumed to have been constant.

Factors from Stephenson and Stephenson's list that seem to bear on the problem are: inherent inconstancy of growth rate, individual variation, and size (age) of the individuals. Several investigators have noted that the growth rate in recent corals generally decreases with increasing age. This general pattern seems to be valid not only for corals but also for many other animals. It is here regarded as the fundamental factor governing the pattern of skeletal growth in *Ankhelasma typicum*. Inherent inconstancy of growth rate and individual variation are factors that may modify this general pattern but whose relative effects are probably neutralized by the population approach used in this study.

If these assumptions are valid, one might go a step farther and attempt to derive a plausible growth curve based on skeletal measurements. Growth curves for living corals are commonly based on measurements of weight, but this character cannot be used for the present analysis owing to incomplete silicification of the skeleton. The linear size measurements, length ($L$) and alar diameter ($d_1$), seem most appropriate for this purpose. Approximate points on the time axes of the growth curve graphs for these characters have been identified and a general pattern of variation in growth rate has been established. Obviously, the time points are not equidistant as shown in text-figs. 3 and 5 because the growth rate decreases with increasing age. One can only guess what the rate of decrease is. Text-figs. 11–13 show growth curves for length and alar diameter plotted against time scales based on progressively decreasing growth rates. In text-fig. 11 the decrease in growth rate is a simple geometric progression and the resulting growth curves are asymptotic. In text-fig. 12 the time scale is based on an arithmetic progression; the growth curves approach a straight line but show slight sinuousity. In text-fig. 13 the time scale is based on a logarithmic progression and the resulting curves are decidedly S-shaped.

Thompson (1948, p. 159–184) has shown that the growth curves of many organisms are S-shaped. Indeed, the S-shaped curve seems to be a basic characteristic of all organic growth. According to Thompson (1948, p. 115), most growth curves are very complex and tend to be simple only in the simplest organisms. Thus, it would not be surprising to find the growth of a coral characterized by a simple S-shaped curve. The association of an S-shaped curve with a logarithmically based growth rate may indicate that the decrease in growth rate in *Ankhelasma typicum* was essentially a logarithmic function.

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# LOWER CARBONIFEROUS BRACHIOPOD FAUNAS FROM OLD CANNINDAH, QUEENSLAND

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ABSTRACT—Brachiopods constitute a major element in the Lower Carboniferous reef and pre-reef faunas from Old Cannindah. They occur in six of the eight known assemblages which range from late Tournaisian to late Viséan in age. Five new species and varieties are described, viz., *Daviesiella cannindahensis*, *Prospira burnettensis*, *Prospira typa* var. *tellebangensis*, *Kitakamithyris globosa*, and *Martinia neoproductoides*, while six existing species and varieties are re-described, viz.: *Rugosochonetes kennedyensis* var. *magnus* Maxwell, *Rhipidomella australis* (McCoy), *Prospira typa* Maxwell, *Ectochoristites wattsi* Campbell, *Brachythyris* cf. *davidis* (Dun) and *Kitakamithyris uniplicata* (Campbell). Type specimens of *Prospira typa* and *P. prima* are refigured.

## INTRODUCTION

THE species described in this paper occur in the Tellebang and Baywulla formations, in the Old Cannindah area. They are associated with molluscan species, previously described (Maxwell, 1960a) as well as abundant corals, now being described by Professor D. Hill.

For her reading of the manuscript and valuable suggestions I am indebted to Professor D. Hill. Dr. K. S. W. Campbell contributed useful advice. The map was drafted by Mr. A. Smith, and the photographs were taken by Mr. Chadwick, both of the University of Queensland. A Research Grant from this University financed the project.

## STRATIGRAPHY

The old Cannindah area is located on the western margin of the Yarrol Basin (Hill, 1951), which was a region of marine sedimentation from Middle Devonian to early Permian time. The stratigraphy of the Yarrol Basin has been described in a previous work (Maxwell, 1960b). At Old Cannindah, two formations are exposed on the western limb of the major Tellebang Anticline. The Tellebang Formation, of late Tournaisian age, consists of shale and subgraywacke, with interbedded limestones in its upper part. It is succeeded by the Viséan Baywulla Formation which was deposited in a reef province on the western side of the Yarrol Basin and consists almost entirely of limestone. The basal 1000 feet are coarsely oolitic, and the overlying non-oolitic, coralline limestones constitute the reef core. Non oolitic crinoidal limestone succeeds the core for 300 feet and this in turn is overlain by a thin 10 feet band of finely oolitic limestone, which defines the upper limit of the formation.

## FAUNAS AND LOCALITIES

Rich and varied faunas occur throughout the beds described above, although greatest concentrations are found at eight horizons. The sequence of faunas and their localities are indicated on the following table. Brachiopod species occur on five of the seven horizons, while the remaining two have corals or molluscs only. The locality numbers correspond with those on the accompanying map and are recorded in the University of Queensland index. The faunal collections on which this work is based are housed in the same University.

## CORRELATION AND AGE

Faunas from horizons 1–4 in the Tellebang Formation are of late Tournaisian age. Their closest affinity is with the Watts, Babbinboon assemblage of New South Wales (Campbell, 1957) although this lacks the abundance of gastropods found in Queensland. Correlation with the Mt. Morgan sequence (Maxwell, 1954) suggest equivalence with the *Schizophoria* and *Chonetes* zones. However, *Schizophoria*, *Syringothyris* and *Cleiothyridina* which are typical of the *Schizophoria* zone at Mt. Morgan are notice-

TABLE 1—STRATIGRAPHIC DISTRIBUTION OF BRACHIOPOD SPECIES

| | Lithology | Horizon | Brachiopod Fauna | Locality |
|---|---|---|---|---|
| Baywulla Formation | Oolitic Limestone | 8. *Palaeacis* | *Daviesiella cannindahensis* | L1958<br>L2060 |
| | Crinoidal Limestone | 7. *Michelinia* | | L2061 |
| | Coralline Limestone (Reef Core) | 6. *Syringopora* | *Kitakamithyris globosa* | L1863<br>L1967<br>L1963<br>L1964<br>L1969<br>L1966 |
| | Oolitic Limestone | 5. *Rhipidomella* | *Rhipidomella australis* | L1961 |
| Tellebang Formation | Subgraywacke, Calcareous Breccia | 4. *Loxonema* | *Rhipidomella australis*<br>*Rugosochonetes kennedyensis* var. *magnus*<br>*Prospira burnettensis, P. typa* var. *tellebangensis*,<br>*Ectochoristites wattsi, Martinia neoproductoides*,<br>*Brachythyris* cf. *davidis, Kitakamithyris uniplicata.* | L1970 |
| | Subgraywacke, Crinoidal Limestone | 3. *Prospira* | *P. burnettensis* | L1979 |
| | Subgraywacke, Oolitic Limestone | 2. *Prospira* | *P. burnettensis* | L1980 |
| | Subgraywacke, Crinoidal Limestone | 1. *Waagenella* | *P. burnettensis* | L1872 |

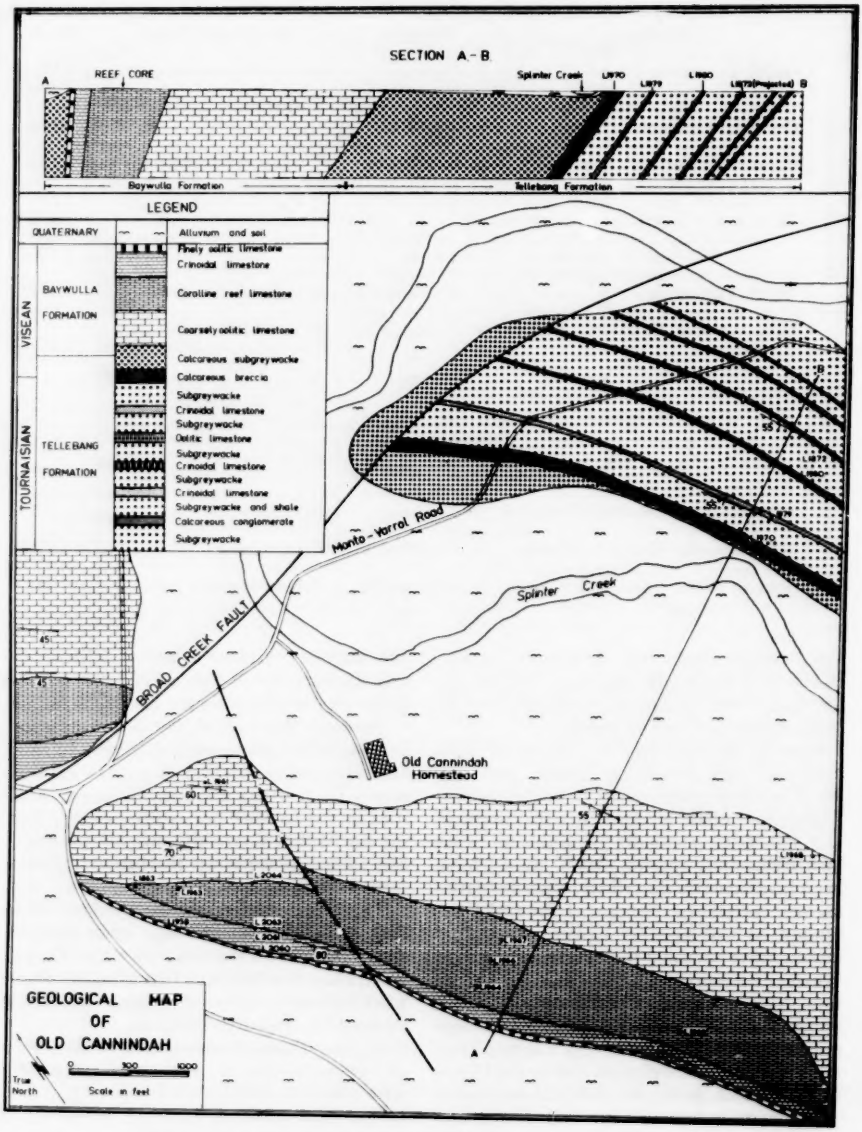
ably absent from the Tellebang faunas. Horizons 5–8 contain species of Viséan age ($D_1$–$D_2$). These faunas are relatively poor in brachiopods but rich in corals.

Generic affinities can be recognized with European and American faunas, although the European relationship is more evident. Except for Japan, which has both European and American elements in addition to its own indigenous species, Asian faunas have been insufficiently described to permit satisfactory correlation. Studies of the Old Cannindah, as well as other Eastern Australian faunas, have revealed their relationship with Western Europe. Furthermore, although numerous genera are common to North America and Australia, the American faunas appear to have closer ties with Europe. During the Upper Devonian as well as the Lower Carboniferous, many brachiopod and gastropod genera appear to have had almost universal distribution, while in some cases this distribution extended to species e.g. *Cyrtospirifer verneuili, Schizophoria resupinata, Phricodothyris lineata, Daviesiella comoides.* The majority of forms common to Australia and America are of this universal kind, and are generally present in the European faunas.

Towards the end of the Lower Carboniferous, faunal relationships altered radically, and with the restriction of marine environments in Western Europe, European affinities in the Queensland faunas waned. During the Middle Carboniferous, South American elements appeared for the first time—*Levipustula levis.*

This link persisted into the Permian, while that with Western Europe grew progressively weaker. At the same time, the Eastern Australian province was becoming more and more isolated and its own typical faunas had evolved by the early Permian.

Of the Tournaisian species, *Rugosochonetes kennedyensis* var. *magnus* is comparable with *Chonetes variolata* d'Orbigny figured by de Koninck (1847, pl. 19, fig. 5, pl. 20, fig. 2) from the Tournaisian of Belgium and *Rugosochonetes upensis* Sokolskaya (1950, p. 27–31 pl. 2) from the Tournaisian DC zone of the Russian Platform. *Prospira typa* resembles




TEXT-FIG 1—Geological Map of Old Cannindah Area, with localities of faunas.

*Spirifer attenuatus* Sowerby, figured by Delépine (1928, pl. 6, fig. 73) from the late Tournaisian—early Viséan of Belgium; de Koninck (1887, pl. 28, figs. 24,25) identified a similar form from the Belgian Viséan as *Spirifer trigonalis* (Martin). A third species resembling *Prospira typa* was figured as *Spirifer tornacensis* by Sarycheva and Sokolskaya (1952) from the late Tournaisian Cherneshinsky subzone of the Moscow Basin. In America, *Spirifer osagensis* Swallow figured by Weller (1914, p. 314, pl. 37) from the Hannibal Sandstone (Tournaisian) and *Spirifer platynotus* Weller (1914, p. 317, pl. 39, figs. 1–6) from the Kinderhook (Tournaisian) are comparable with *Prospira typa* var. *tellebangensis* and *P. typa s.s.* respectively.

*Prospira burnettensis* is nearest to *Spirifer romerianus* de Koninck (1887, p. 125, pl. 29, figs. 25–27) from the early Tournaisian of Belgium. *Spirifer tornacensis* de Koninck, figured by Sarycheva and Sokolskaya (1952) from the late Tournaisian of the Moscow Basin is also similar. *Ectochoristites wattsi* also has affinities with the European species *Spirifer cinctus* de Koninck (1887, pl. 24, figs. 6,7) from the Belgian Tournaisian. Other similar species include *Spirifer humerosus* Phillips, figured by Hayasaka (1924) from the Viséan Onimaru Formation of Japan, and *Spirifer gregeri* Weller (1914) from the Chouteau limestone of North America.

*Martinia neoproductoides* resembles the species identified as *Spirifera glabra* by Davidson (1858, pl. 12, figs. 9,10) from the Lower Carboniferous of England, by Delépine (1928, pl. 6, fig. 1) from the late Tournaisian—early Viséan of Belgium, and by Sarycheva and Sokolskaya (1952, pl. 64, fig. 361) from the Viséan of the Moscow Basin. In all three cases, the form is somewhat broader than the Queensland species. *M. hemisphaerica* Ainor (1957, pl. 3, fig. 1) from the Lower Carboniferous of the Central Urals is also a broader form. Related species from America include *M. contracta* Meek and Worthen and *M. sulcata* Weller from the Chester Group.

The only foreign species similar to *Brachythyris* cf. *davidis* is *B. willbourni* Muir-Wood (1948, pl. 8, figs. 1–3) from the Viséan faunas of Malaya.

*Kitakamithyris uniplicata* differs from most foreign species in its weaker convexity. *K. semicircularis* Minato (1952, p. 171) from the Lower Carboniferous Hikoroiti Series, Japan is the nearest form.

The Viséan faunas of Old Cannindah are poorer in brachiopods, the main element being coralline. *Rhipidomella australis* which occurs in the earliest Viséan (5) as well as the preceding Tournaisian (4) horizons, is indistinguishable from species in the European and North American faunas of late Tournaisian—early Viséan age e.g. *R. michelini* (L'Eveillé) from Belgium (Demanet, 1934, pl. 2, fig. 6a, Delépine, 1928, p. 14); *R. burlingtonensis* (Hall), *R. missouriensis* (Swallow) and *R. oweni* (Hall and Clarke) figured by Weller (1914) from the late Tournaisian faunas of North America. *Kitakamithyris globosa* resembles the species *K. tyoanjiensis* Minato (1951, p. 374) from the Lower Carboniferous Hikoroiti Series of Japan, *K. triseptata* Campbell (1955, p. 379) from the Tournaisian of New South Wales and *Phricodothyris lineata* (Martin) figured by George (1932) from the Viséan of England. *Daviesiella cannindahensis* has close affinity with *D. llangollensis* (Davidson) and *D. comoides* (Sowerby) from Viséan faunas of England (Cope, 1933) Belgium (Delépine, 1928) Russia (Sokolskaya, 1950, Sarycheva and Sokolskaya, 1952). *Daviesiella aspinosa* (Dun, 1905, pls. 19–20) from probably Viséan faunas in New South Wales is very similar. *Daviesiella* does not appear in North America or Japanese faunas. In addition to brachiopod evidence, the gastropod species *Waagenella microstriata* and *Straparolus subdionysii* from horizon 1, and *S. australis*, *Euphemites minutus*, *Loxonema lamellosa* and *Austroworthenia levis* from horizon 4, support the correlations suggested above. Evidence for the Viséan age of the Baywulla Formation (horizons 5–8) is provided by the rich coral faunas.

## SYSTEMATIC DESCRIPTIONS

### Superfamily CHONETACEA Shrock and Twenhofel 1953

### Family CHONETIDAE Hall and Clarke 1893

### Genus DAVIESIELLA Waagen 1884.

*Daviesiella* Waagen, 1884, p. 613. Hall and Clarke, 1893, p. 317, fig. 26; Paeckelmann, 1930, p. 220–222; Cope, 1943, p. 199–274; Sokolskaya, 1950, p. 86–93.

*Generotype.*—(by subsequent designation

of Oehlert 1887, p. 1279)—*Productus llangollensis* Davidson 1862, p. 277, pl. LV, figs. 9,10 from the Carboniferous Limestone, Llangollen, Denbighshire, England; Viséan, Lower Carboniferous ($S_2$–$D_1$ zones).

*Diagnosis.*—Large, concave-convex, somewhat globose shell, semicircular to subcircular in outline, straight, wide hinge line; cardinal areas in both valves; cardinal process large, trilobed; ornament of fine costae and minute pits; ventral valve with low folds; ventral median septum separates long adductor scars, enclosed by pair of flabellate diductors, extended anteriorly and sometimes differentiated into anterior and posterior diductors; strong teeth, bordered by sub-dental pits; dorsal median septum low, separating adductor scars; internal surface of both valves roughened with pustules and small ridges.

*Remarks.*—The genus was erected by Waagen (1884, p. 613) "for the reception of such forms as *Productus llangollensis* Dav., and *Prod. comoides* Sow., which are characterized by cardinal teeth and a second pair of adductors in the ventral valve. The other characters are like those of *Productus.*" Oehlert (1887, p. 1279) cited *P. llangollensis* as the type species, and subsequent authors (Paeckelmann, 1930, p. 122), Cope (1943, p. 203) accepted Oehlert's designation. However Sokolskaya (1950, p. 86) cited *Productus comoides* Sowerby, 1823 as the generotype. Cope (1933, p. 200) has shown that *P. comoides*, and *P. llangollensis* are certainly distinct species, and not conspecific as originally believed by Davidson. In view of this, Sokolskaya's citation of *Productus comoides* Sowerby as the generotype is erroneous.

*Range.*—*Daviesiella* occurs in the Lower Carboniferous of Europe. In England, *D. llangollensis* is restricted to the Viséan $S_2$–$D_1$ beds, but earlier species occur in the Upper Tournaisian ($C_2$–$S_1$) faunas of Belgium and France.

In Russia the genus occurs in the Tulian, Alexinian and Mikailopian subzones of the Viséan of the Moscow Basin.

### Daviesiella cannindahensis, n. sp.
Pl. 19, figs. 16–19

*Holotype.*—F.28655 Univ. Queensland Collection, from L2060, West of Old Cannindah Homestead, County Yarrol, Queensland; Viséan.

*Diagnosis.*—As for genus; ventral valve sinuate, dorsal valve with low median fold; ventral median septum narrow, high; muscle scars weakly impressed, anterior region indistinct, dorsal adductors dendritic, grooved impressions posterior to adductors; dorsal median septum thick, low, short.

*Description.*—(External). The ventral valve is large, convex and sinuate with low folds or flexures on its lateral slopes. Greatest width occurs near the straight hinge line, which is bordered by a moderately high striated, cardinal area. A broad triangular delthyrium is closed by an arched deltidium. An ornament of fine sinuous costae and minute inter-costal pits covers both the ventral and dorsal valves. In cross section, the costae are rounded while the intervening sulci are sharply V-shaped.

The dorsal valve is concave, and flexuous, and has a wide straight hinge line, with a low, laterally striated, cardinal area. An arched triangular chilidium covers the notothyrium.

(Internal). The internal characters of the shell are weakly developed in most specimens examined, but some of the older individuals have their structures more clearly defined. Thickening of the shell in the postero-lateral region of the ventral valve accentuates the teeth, sub-dental pits, and to a lesser extent the flabellate diductor muscle scars. The adductor muscle scars are less distinct, but are enclosed by the diductors and separated by a thin, fairly high median septum. Secondary diductor scars can not be distinguished, but the uneven surface of the shell in the region anterior to the septum suggests that such muscles may have been attached there.

In the dorsal valve, a short, squat cardinal process fills the notothyrium, and is buttressed anteriorly by a thickened median septum which narrows abruptly and ends about 13 mm. from the hinge line. Two deep dental sockets occur on either side of the process and are bordered by strong cardinal ridges, which flatten laterally. In the angles between the median septum and the cardinal ridges, two sub-triangular impressions occur, which are marked by sinuous ridges and grooves. The adductor scars consist of two sub-triangular, dendritic markings on slightly raised platforms, separated by the thin end of the median septum, and bordered by the

inner sides of the grooved impressions. No brachial ridges can be distinguished.

*Dimensions.*—

| | | *Holotype* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|---|
| Length | Ventral | 50 | >40 | — | — | >35 | >29 |
| | Dorsal | — | — | >37 | >33 | — | — |
| Width | Ventral | 76 | >80 | — | — | 78 | 66 |
| | Dorsal | — | | >90 | >46 | — | — |
| No costae/10 mm. 20 mm. from umbo. | | 26 | — | — | 32 | — | 26 |

*Remarks.*—*D. cannindahensis* resembles other members of the genus in its external characters, but has quite distinctive internal features in the dorsal valve. Its dorsal adductor scars are dendritic, while grooved impressions are situated between the adductors and the cardinal margin. The true nature of these impressions is not apparent, but possibly they also served for the attachment of adductor muscles.

The musculature of the ventral valve is more difficult to distinguish, but appears to be typical of the genus.

In Europe, the species *D. llangollensis* Davidson and *D. comoides* Sowerby occur mainly in the Viséan. In Russia, Sarycheva and Sokolskaya 1952 (p. 71–74, pl. 12, figs. 77) have described *D. comoides* from the Viséan of the Moscow basin. *D. cannindahensis* has affinities with the Russian, Belgian and British forms of *D. comoides*.

*Chonetes aspinosa* Dun 1905 (p. 69–71, pls. 19,20) from the Lower Carboniferous (probably Viséan) faunas of Binge Berry, Torryburn and Stroud, New South Wales, belongs to *Daviesiella* Waagen. In general, it is a larger form than *D. cannindahensis*, with a relatively lower cardinal area, less sinuate pedicle valve and smaller median septum.

*Daviesiella cannindahensis* occurs in the Baywulla Formation in the Yarrol district, in beds of equivalent age in the Mundubbera district. At the type locality of Old Cannindah, the species occurs in detrital limestones, immediately overlying the main reef limestone which contains a rich coralline fauna of Viséan age. It is associated with *Palaeacis*.

Genus RUGOSOCHONETES Sokolskaya 1950

*Rugosochonetes* Sokolskaya, 1950, p. 23–41; Maxwell, 1954, p. 19–21; Campbell, 1957, p. 65–66.

*Generotype.*—(by original designation) *Orthis hardrensis* Phillips, 1841, p. 138, pl. 58, fig. 104; from Hardraw, Yorkshire; Lower Carboniferous (Viséan).

*Diagnosis.*—Small, transverse, weakly concavo-convex, shell; cardinal spines always present; muscle scars medium to large; ventral median septum small and low.

*Remarks.*—The status of the generotype has been discussed in an earlier paper (Maxwell, 1954, p. 20), and considered by Campbell (1957, p. 65). The holotype of *Orthis hardrensis* Phillips, automatically fixed through Sokolskaya's original designation of the generotype of *Rugosochonetes*, has been lost, together with topotypes. Further, Phillips original description and figures are too poor to allow certain identification of the species in other material from Hardraw, the type area. Consequently, any interpretation of the genus must remain in doubt until the generotype has been strictly defined, and it seems that this can only be done through designation of a neotype. Material examined by the author, in the British Museum of Natural History, collected from Hardraw, was regarded as probably being conspecific with Phillips' specimens.

RUGOSOCHONETES KENNEDYENSIS var. MAGNUS
Maxwell, 1954.
Pl. 19, fig. 1

*Rugosochonetes kennedyensis* var. *magnus* Maxwell, 1954, p. 44–45, pl. V, figs. 11–13.
*Rugosochonetes werriensis* Campbell, 1957, p. 66, pl. 12, figs. 27–30.
*Chonetes gloucesterensis* Cvancara, 1958, p. 866–868, pl. 111, figs. 1–7.

*Holotype.*—F.15311 Univ. Queensland Collection; from L1293, north of Duck Pond Creek, Mt. Morgan District, Queensland; Viséan (*Cleiothyridina* and *Spirifer* zones); other locality L1970, Portion 91, Parish Cannindah, Queensland.

*Diagnosis.*—Shell small, moderately concavo-convex; outline semicircular; eight cardinal spines; 50 to 80 striae; papillose internal surface; low ventral median septum and dorsal median ridge; strong cardinal ridges.

*Remarks.*—*Rugosochonetes kennedyensis s.s.* and its variety *magnus* have been described in detail in a previous paper (Maxwell, 1954). Campbell (1957, p. 66) proposed the name *R. werriensis* for the form from Watts, Babbinboon, New South Wales, but there is little doubt that it is closely allied to the Queensland variety. It differs in having slightly coarser striation (30 per 10 mm. on *R. werriensis*, 34 per 10 mm. on *R. kennedyensis* and 38 per 10 mm. on *R. kennedyensis* var. *magnus*). In view of the morphological similarity, there seems good reason for regarding the form from Watts, Babbinboon as conspecific with *R. kennedyensis* var. *magnus*.

*Chonetes gloucesterensis* Cvancara, 1958, is similar to both *Rugosochonetes kennedyensis* var. *magnus* and Campbell's form *R. werriensis* differing only in its slightly finer ornament (40 to 46 per 10 mm.). Reasons for separating this species are not clear, and the author believes that no purpose was served by erecting a new species.

The variety *magnus* occurs in early Viséan beds at Mt. Morgan and in late Tournaisian beds at Old Cannindah. The New South Wales forms have been found with faunas determined as Upper Tournaisian in age.

Superfamily DALMANELLACEA Schuchert and Cooper 1932

Family RHIPIDOMELLIDAE Schuchert 1913, emend. Schuchert and Cooper 1930.

*Diagnosis.*—Subcircular outline; broad flabellate diductor scars, enclosing elliptical adductor scars; short brachiphores; no fulcral plates.

*Remarks.*—Members of this family are distinguished from the closely related schizophoriids by the diductor scars enclosing the adductors. In all other characters, the two groups are similar. The family has a wide range from Silurian to Permian.

Genus RHIPIDOMELLA Oehlert 1890

*Rhipidomella* Oehlert, 1890, p. 372; Schuchert and Cooper, 1932, p. 133; Demanet, 1934, p. 37–44; Campbell, 1957, p. 51–56; Cvancara, 1958, p. 853–856.

*Generotype.*—(by original designation) *Terebratula michelini* L'Eveillé, 1835, 2, p. 39, pl. 2, figs. 14–17; from (?)Tournai, Belgium, Lower Carboniferous.

*Diagnosis.*—Small to medium sized, unequally biconvex, subcircular shell; hinge line short; area low; ornament of hollow costae, few growth lines; incipient dental plates; large diductors enclosing elongate adductors; large cardinal process, widely divergent brachiophores; dorsal muscle scar quadripartite, divided by low median ridge.

*Remarks.*—The genus has been treated in detail by Schuchert and Cooper 1932, p. 133 and Campbell 1957, p. 51–52. However, no recent author has redescribed or refigured the holotype of *Terebratula michelini* L'Eveillé, the type species, and the present author has not been able to examine either the original figures or the original material. Interpretation of the type species has been based on that of Schuchert and Cooper 1932, and Davidson 1862. Although the type species occurs in the Lower Carboniferous, the genus ranges through from the early Silurian to the Permian.

RHIPIDOMELLA AUSTRALIS (McCoy 1847)
Pl. 19, figs. 2–6

*Orthis australis* McCoy, 1847, p. 234, pl. 13, figs. 4,4a.

*Rhipidomella australis* Dun, 1900, p. 79, pl. 21, figs. 10,11; Campbell, 1957, p. 52–54, pl. 12, figs. 13–20.

*Lectotype.*—(by subsequent designation, Campbell, 1957, p. 52) E10663, Sedgwick Museum, Cambridge; from Lewinsbrook, New South Wales. Lower Carboniferous. Localities of specimens figured in this paper L1961 and L1970, Portion 91, Parish of Cannindah.

*Diagnosis.*—Ventral valve weakly convex, dorsal valve moderately convex; outline subcircular; 30–36 costae per 10 mm. at commissure; short, widely divergent (65°–80°) dental plates; muscle field enclosed by low ridge extending from ends of dental plates; low ventral median septum; strong, pointed brachiophores, diverging at 70°–80°; cardinal process strong, variable; low median ridge.

*Remarks.*—The species has been adequately described by Campbell (1957, p. 52),

who stated that it was indistinguishable from *R. michelini* from Belgium as interpreted by Demanet (1934). Dun (1900, p. 80) separated the two species on the basis of the muscle scars of the dorsal valve, *R. australis* having less distinctly defined posterior elements and more elongate muscle field. Since neither author had been able to examine the type material of *R. michelini*, the true status of *R. australis* must remain in doubt.

*R. australis* is comparable with *R. michelini* from Europe, *R. burlingtonensis* Hall, *R. missouriensis* Swallow and *R. oweni* Hall and Clarke from North America—species of late Tournaisian—early Viséan age. In Australia it ranges through the Lower Carboniferous of New South Wales and Queensland, but is most abundant in beds of Tournaisian age. It has been found in the Yarrol district and in the Rockhampton district in beds well below the Viséan ($D_1$–$D_2$) limestones.

Superfamily SPIRIFERACEA Waagen 1883.
Family SPIRIFERIDAE King 1846.
Subfamily CYRTIINAE Fredericks 1926.
Genus PROSPIRA Maxwell 1954.

*Prospira* Maxwell, 1954, p. 35–37, pl. 4, figs. 4–8.

*Generotype.*—(by original designation) *Prospira typa* Maxwell, 1954, p. 35–36, pl. 4, figs. 6–8; from L1291, Stony Creek, Mt. Morgan District, Queensland; Lower Carboniferous. Refigured pl. 20, figs. 10–14.

*Diagnosis.*—Shell transverse, biconvex; sinus and folds small, smooth or weakly costate; lateral costae rounded; microscopic radial lirae over entire surface; dental plates short, thickened; dorsal median septum small or absent.

*Remarks.*—The affinities of *Prospira* with previously described genera were considered in the original description, and particular reference was made to *Fusella* McCoy, *Brachythyrina* Fredericks, *Sinospirifer* Grabau, *Cyrtospirifer* Nalivikin, *Mucrospirifer* Grabau, *Platyrachella* Fenton and Fenton and *Brachyspirifer* Wedekind. Since the erection of *Prospira*, Campbell (1957, p. 31) has proposed another genus *Unispirifer* for similar forms in the Carboniferous of N.S.W. In addition to N.S.W. forms,' he included such species as *Spirifer tornacensis* de Koninck, *S. clathratus* McCoy, *S. forbesi* Norwood and Pratten, *S. vernonensis* Weller and *S. baiani* Nalivkin, and separated them from *Cyrtospirifer* on the basis of sinal costation—*Cyrtospirifer* having seven or more sinal costae, with a median and later intercalated costae. *Unispirifer* was distinguished by fewer costae, with no intercalations between the primaries. Campbell separated *Unispirifer* from *Prospira* by coarser costation, less numerous sinal costae, weaker dental lamellae and smaller size of *Prospira*.

Examination of the N.S.W and Queensland material and consideration of the *Cyrtospirifer-Prospira* plexus in Eastern Australia leads one to the conclusion that *Unispirifer* is closely related to *Prospira*, if not congeneric. Differences quoted by Campbell may not be of generic value, since members of the one sometimes show variation as wide as that used to separate the two genera. However, it seems that the forms ascribed to *Unispirifer* are generally more costate, and possibly represent earlier members of the *Unispirifer-Prospira* group. In view of this, recognition of its generic status may facilitate stratigraphic and taxonomic studies of these spiriferids.

In the original description of *Prospira*, it was stated that the genus was identical with that interpreted by Buckman (1906, p. 26) and McCoy (1844, p. 128, 132–133) as *Fusella* McCoy. However, as was previously indicated, neither author was accurate in his interpretation, since the holotype of *Spirifer fusiformis* Phillips (1836, p. 217, pl. 9, figs. 10,11) on which the genus was based, does not display the "eight round, smooth ribs on each side of the mesial fold" (McCoy 1844, p. 132). Davidson (1862, pl. 13, figs. 15,15a) refigured Phillips' original specimen and stated (p. 57) that it "is nearly smooth, showing indications of radiating striae, but at the umbone and in the vicinity of the cardinal edge." Davidson pointed out that the shell was partly decorticated and that it was impossible to determine the exact nature of the surface ornament.

In view of this, it seems that the choice of *Spirifer fusiformis* as a generotype was unfortunate, and that the true character of *Fusella* cannot be established until the type species has been identified in well preserved material from the type area of Bolland, Yorkshire. Identification may be difficult, if not impossible, since the Bolland fauna contains several small, costate species all of which are

similar, and, in the decorticated state, inseparable.

In spite of the uncertainty of identity of *Spirifer fusiformis*, it seems improbable that the "striae" referred to by Davidson could develop into "eight, round smooth ribs" (McCoy) or "ribs coarse laterally, tending to be deficient medianly" (Buckman 1906, p. 29). Both authors allowed a wide range of variability in their interpretation of the genus —McCoy included *Spirifer rhomboidea* Phillips and *Spirifera bicarinata* McCoy the former with a costate sinus, the latter with a broad, deep smooth sinus. Buckman included nine species, ranging from those with strongly costate sinus to others with a deep smooth sinus. The species approaching most closely to their interpretation of *Fusella* is *Spirifera rhomboidea* Phillips.

The erection of *Prospira* and *Unispirifer* was based primarily on costation, but other characters, one of which included shell shape, are significant. Comparison of both genera with Phillips' original figure of *Spirifer fusiformis* shows the latter to be extremely transverse, its length:width ratio being 1:3, whereas *Prospira's* ratio varies from 1:2 to 2:3 and *Unispirifer's* is 1:2.

Beznosova (1959, p. 58–80) discussed *Fusella* and described ten species from the Kuznetsk Basin, referring all of them to *Fusella*. She included *Unispirifer* Campbell in its synonymy, and questioned the validity of *Prospira*. In using *Fusella*, Beznosova accepted McCoy's and Buckman's interpretations, without first attempting to establish the true nature of the generotype. None of the species figured by Beznosova resemble *Spirifer fusiformis* Phillips, either in ornament or proportions, and they would be best referred to *Unispirifer* and *Prospira*. Minato (1951, 1952) also described the species *Fusella nipponotrigonalis* from the Kitakami Mountains of Japan. This species has affinities with *Prospira*.

The Queensland Upper Palaeozoic *Cyrtospirifer-Prospira plexus* was studied by the author in an unpublished thesis (1952). Four successive groups—*Cyrtospirifer sinensis* var. *australis* and *C. reidi*, *Unispirifer morganensis*, (originally referred to *Sinospirifer*), *Prospira prima* and *Prospira typa* were considered, and the following trends recognized:

1. Degeneration of the ornament of the median segments of both values.
2. Increase in the coarseness of the ornament of the lateral slopes.
3. Decrease in the magnitude of the medial segments.
4. Transverse extension of the shell outline.
5. Gradual increase in the size of the individuals, except in the case of *Prospira prima*.
6. Decrease in the convexity of the valves.

The most striking trend was seen in the degeneration of the sinal plications, while the size of the medial segments and the coarseness of the lateral costation also showed recognizable changes. The last three trends were less evident. As a result of this work, the author felt justified in erecting the genus *Prospira* to separate the younger, more transverse shells with degenerate sinal costation, from the earlier members of *Cyrtospirifer*.

Work on *Cyrtospirifer* and related genera has emphasized the importance of sinal costation in separating the various groups, but at the same time, it has also revealed the danger of over estimating the value of detailed variation in this character. The extreme view taken by Gatinaud (1949, 1950) is not compatible with that of the author, since it is believed that in many of Gatinaud's statistical analyses, the range of variation found within his species is wider than that between different species (e.g. *Cytrospirifer verneuili* and *Tenticospirifer*). Many of the differences in sinal configuration appear to have less than subspecific value, while others may be of generic significance. Consequently while detailed observation and measurement of sinal costation facilitates comparison, the assessment of similarities and differences remains a matter of personal opinion. In the Eastern Australian forms an almost continuous range of "sinal" variation exists between the early and later species, but it is evident that the variation is a progressive one, and the end members are readily distinguished, viz. *Cyrtospirifer reidi*, with sinal formulae ranging from 3+I+1+1x+1+1x +1+I+3 to 1+I+3+I+1, and *Prospira typa*, commonly with sinal formula 1+I+I +1 (using Grabau's terminology, I=Primary, 1x=Bifurcation). However, species such as *Unispirifer morganensis* (Maxwell, originally referred to *Sinospirifer*) with sinal formulae such as 1+I+1+I+2 and 1+I

+2+I+1 have the external character of degenerate *Cyrtospirifer*, but generally show a thickening of the apical region of the shell. *Unispirifer* figured by Campbell (1957, p. 69, fig. 10) having the formula 2+I+1+1x +I+2 and 1+I+1+1x+I+1 is in a similar position of generic uncertainty if sinal costation is used to the exclusion of other characters.

*Prospira* occurs in the Lower Carboniferous Septimus Limestone faunas of the Bonaparte Gulf area of Western Australia. The species *Spirifer nodai* Tachibana (1956, p. 11–13, pl. 1, figs. 1–4) from the Lower Carboniferous of Nagasaka probably belongs to *Prospira* being most similar to *P. typa* in the Australian forms. *Fusella nipponotrigonalis* Minato (1952, p. 160, pl. 11, fig. 3) from Jumonzi stage, in the Kitakami Mountains also belongs to *Prospira*. Species probably belonging to this genus occur in North American and European faunas.

*Range.*—Upper Tournaisian and early Viséan. Since its original discovery in the Mt. Morgan district, *Prospira* has been found in the Cania, Yarrol and Mundubbera districts further south, in the Yarrol basin. In these districts it is associated with late Tournaisian and Viséan faunas.

PROSPIRA BURNETTENSIS n. sp.
Pl. 20, figs. 1–7

*Holotype.*—F. 28586 University of Queensland Collection; from L1872, base of Mt. Cannindah, Portion 9, Parish Cannindah, County Yarrol, Queensland; late Tournaisian. Other localities L1970, L1979, L1980.

*Diagnosis.*—As for genus; 2 primary sinal costae, sometimes bifurcating, and weak intercalated median costa.

*Description.*—(*External*). The shell is strongly to moderately biconvex, approximately twice as wide as it is long, with alate cardinal extremities. The ventral umbo is slightly incurved over a linear, curved area which is vertically striated. The medial segment of each valve is prominent. The sinus is bordered by two strong primary costae which tend to bifurcate anteriorly, while a weak intercalated median costa is invariably present. The dorsal fold consists of 2 thick primary costae, bordered by deep grooves. The primary costae bifurcate anteriorly. The sinal formula varies from I+1+I to I+1x+1 +1x+I. The lateral costae are more rounded than those of *P. prima s.s.*, and are separated by rather sharp furrows. The microscopic ornament of fine radial lirae and concentric growth lamellae is typical of the genus. The number of costae per 5 mm., measured at a distance of 5 mm. from the umbo averages 7.

(*Internal*). The internal structure is the same as that of *P. prima*. The umbonal region of the ventral valve is generally less thickened, and the dental plates and delthyrial plate are more readily observed. The dental plates are short, divergent and joined centrally by the delthyrial plate. The muscle scar is partly enclosed by the extended bases of the dental plates. No median structure divides the muscle scar. Its surface is generally striated, its outline rhomboidal.

The dorsal valve carries a small striated cardinal process, situated between divergent socket plates, which give rise to the crura. A minute median ridge extends anteriorly from the cardinal process.

*Dimensions.*—

| | *Ventral Valves* | | | | *Dorsal Valves* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Width | 24 | 28 | 24 | — | 18 | 25 | 23 | 30 | 34 | 25 |
| Length | 17 | 15 | 13 | — | 10 | 16 | 15 | 10 | 10 | 11 |
| Muscle Scar length | — | 4 | — | 5 | — | — | — | — | — | — |
| Muscle Scar width | — | 3 | — | 3½ | — | — | — | — | — | — |

*Remarks.*—*P. burnettensis* occurs in a fauna of late Tournaisian-early Viséan age, which is overlain by limestones containing Viséan corals and brachiopods. It is closely related to the Mt. Morgan species, *P. prima* (pl. 20, figs. 8,9) the minor differences in size and ornament being due possibly to environmental modification. A similar form (F.20276 University of Queensland Collection) has been identified in the Septimus limestone of Western Australia, where the associated fauna suggests a late Tournaisian age.

Of the Russian species, it is most similar to *Spirifer bijaensis* Semichatova, figured by Sarycheva and Sokolskaya 1952 (p. 186, pl. 52) from the Namurian faunas of the Moscow Basin, and *S. tornacensis* de Koninck figured by the same authors from the late Tournaisian Cherneshinsky subzone. The Belgian form with closest affinities is the one figured and described by de Koninck 1887 (p. 125, pl. 29, figs. 25–27) as *Spirifer romerianus* from the early Tournaisian of Tournai. In America Weller (1914, p. 322, pl. 40, figs. 1–13) has figured *Spirifer louisianensis* Rowley from the Tournaisian Chouteau Limestone, and this species shows similarities to *P. burnettensis*. *Spirifer biplicoides* Weller (1914, p. 322, pl. 39, figs. 27–30) from the Kinderhookian is more similar to *P. prima*.

PROSPIRA TYPA Maxwell 1954
Pl. 20, figs. 10–14

*Prospira typa* Maxwell 1954, p. 35–36, pl. 4, figs. 6–8.

*Holotype.*—F. 15251, University of Queensland Collection; from L1291 Stony Creek, Mt. Morgan District, Queensland. Late Tournaisian.

*Diagnosis.*—Strongly biconvex shell; high, curved, striated area; short, thickened dental lamellae.

*Remarks.*—The species has been described in detail (Maxwell, 1954, p. 35–36). Its diagnostic features are—strongly biconvex, transverse shell, with high, curved, transversely striated area; costate, micro-lirate surface with degenerate sinal costation; short, thick dental lamellae.

In the original description, emphasis was placed on the thickened dental plates and weak costation of the sinus. No sinal formula was quoted. However topotype material has sinal formulae ranging from 1+2+1 to 1+1+1+1. Normally, costae in the sinus are so weakly developed that they are difficult to define, and the value of sinal formulae is lost.

So far the species has been found only in beds of late Tournaisian age.

PROSPIRA TYPA var. TELLEBANGENSIS, n. var.
Pl. 20, figs. 15–23

*Type specimen.*—F. 28593 University Queensland Collection; from L1970, Portion 9, Parish Cannindah, County Yarrol, Queensland. Late Tournaisian.

*Diagnosis.*—Moderately convex, with broad sinus and distinct sinal costae.

*Remarks.*—This variety has been proposed for the form found in the Old Cannindah area. It is distinguishable from the species *s.s.* by its lesser convexity, broader sinus and less degenerate sinal costae. Sinal formula—1+1+1+1+1—is still difficult to determine because of the poor definition of the costae.

There seems little reason for regarding this as a distinct species, since it is so similar to *P. typa*. Modification of convexity and sinal shape can hardly be regarded as reflecting specific differentiation. Similarities with foreign species have been discussed under the chapter on correlation and age.

*Range.*—Late Tournaisian.

Genus ECTOCHORISTITES Campbell 1957

*Ectochoristites* Campbell 1957, p. 71–76, pl. 15, figs. 1–7.

*Generotype.*—(by original designation) *Ectochoristites wattsi* Campbell 1957, p. 73–76, pl 15, figs. 1–7; from Watts, Babbinboon; New South Wales; Upper Tournaisian.

*Diagnosis.*—Subequally biconvex shell, maximum width at hinge; area high, curved, sub-rectangular, grooved; entire surface costate, with bifurcations; dental plates short, thick; crural plates short.

*Remarks.*—The generic status of *Ectochoristites* is not beyond doubt. As Campbell noted, it has the external characters of *Choristites* Fischer de Waldheim, but differs in that its dental plates are short and divergent. Similar features distinguish it from *Yatsengina* Semichatov. However, the other genera which Campbell considered as having affinities with *Ectochoristites*, viz. *Eochoristites* Chu and *Palaeochoristites* Sokolskaya, are less readily separated. *Palaeochoristites* was erected with *Spirifer cinctus* Keyserling as the generotype, and as far as the author is aware, the internal structures of this species, based on material from the type area, are not known. The structure figured by Sokolskayi 1941 and Sarycheva and Sokolskayi 1952 (p. 196, fig. 174) is not markedly different from that of *Ectochoristites*. On the other hand, Keyserling's original figures reveal an ornament in which bi-

furcation is extreme and the costae are flat rather than rounded. *Eochoristites* Chu has longer dental plates that those of *Ectochoristites*, as well as fewer, coarser costae.

The significance of these differences in costation and dental plates is difficult to assess, and cannot be fully appreciated until variation studies have been made on the three genera concerned.

So far *Ectochoristites* has been found in the Lower Carboniferous of Eastern Australia, although species believed by Campbell (1957, p. 76) to belong to *Ectochoristites* occur in North America and Europe in beds of Tournaisian, Viséan and Namurian age.

ECTOCHORISTITES WATTSI Campbell 1957
Pl. 19, figs. 15a–c

*Ectochoristites wattsi* Campbell, 1957, p. 73–76, pl. 15, figs. 1–7.

*Holotype.*—F. 1868 University New England Collections; Watts, Babbinboon; Lower Carboniferous (Upper Tournaisian). Specimen figured in this paper from L1970, Portion 91, Parish Cannindah.

*Diagnosis.*—Subequally biconvex shell, maximum width at hinge; area high, curved, sub-rectangular, grooved; entire surface costate, with bifurcations; dental plates short, thick; crural plates short.

*Description.*—The shell is strongly biconvex, with a high, arched ventral umbo. In outline, it is approaching semicircular, with maximum width at or near the hinge line. The cardinal area is high, sub-rectangular, concave and transversely striated. It is intersected by a broad, open delthyrium with an average angle of 54°. Twenty-five to thirty costae occur on each lateral slope and as many as twenty occur in the sinus. Sinal formulae range from 2+Ix+1xx+Ix+2 to 1+1x+Ixx+1x+1 (where Ix = bifurcated primary, 1x = bifurcated secondary, Ixx = twice bifurcated). Costae in the medial segment of the sinus are finer than the others. The dorsal fold has a corresponding costal arrangement and is bordered by grooves slightly deeper than the normal inter-costal grooves.

Internally, the ventral valve is characterized by short, thick, divergent dental plates, which are directed medially for about half their height, and then curve laterally towards the valve floor. The umbonal and delthyrial cavities are much reduced by shell thickening. A low median ridge separates narrow adductor scars, which are partly enclosed by weakly impressed diductor scars. Thick crural plates diverge from the cardinal process. A low median ridge extends anteriorly along the valve floor.

*Dimensions.*—

| | *Length* | *Width* | *Height of Area* |
|---|---|---|---|
| (Ventral Valve) | 37 mm. | 39 mm. | 5 mm. |

*Remarks.*—Campbell (1957) has discussed the affinities of the species with *Spirifer gregeri* Weller, *Brachythyrina bisulcatus* var. *roscobiensis* and var. *acuticardinalis* Reed from the Lower Carboniferous of North America and Europe. In the European faunas, de Koninck (1887, p. 108–109, pl. 24, figs. 6,7, pl. 26, figs. 1–4) figured and described forms from the Lower Carboniferous limestones of Chanxhe, Comblain-au-Pont, and Tournai, referring them to *Spirifer cinctus*, now the generotype of *Palaeochoristites*. De Koninck noted the poor development of dental plates, and his figures reflect external characters almost identical with those of *E. wattsi*. If *Ectochoristites* is a valid genus, then it seems probable that de Koninck's form rightly belongs to it.

Hayasaka (1924, p. 42–43, pl. 6, figs. 1–5) figured a species from the Viséan fauna of Onimaru in western Echigo, Japan, which he identified as *Spirifer humerosus* Phillips. The internals of Hayasaka's species are not known, but externally it is similar to *E. wattsi*.

In Queensland, *E. wattsi* has been found only at the one horizon, where it is associated with a fauna of Upper Tournaisian age.

Subfamily MARTINIINAE Waagen 1883
Genus MARTINIA McCoy 1844

*Martinia*, McCoy, 1844, p. 125; Buckman, 1908, p. 30. George, 1927, p. 106–119; *Pseudomartinia*, Leidhold, 1928, 109, p. 82–84; Muir-Wood, 1951, p. 109–112; Dunbar, 1955, p. 150–154.

*Generotype.*—(by subsequent designation, Buckman 1908, p. 30). *Spirifer glaber* J. Sowerby 1820 III, p. 123, pl. 269, from Derbyshire; Lower Carboniferous.

*Diagnosis.*—Shell non-costate or with incipient costation near the umbo; hinge narrow; medial fold entire, no dental plates.

*Remarks.*—George (1927) in a detailed study of McCoy's genera *Brachythyris* and *Martinia*, recognized three groups in what was probably one main plexus, viz:

1. *Martinia* McCoy—smooth or partly costate.
2. *Brachythyris pinguis* group—costate, with grooved fold.
3. *B. integricosta* group—costate, with ribbed fold.

The close relationship of *Brachythyris* and *Martinia* was further discussed by Maxwell (1954, p. 26–27) and, although their separation, based mainly on the degree of costation, was possibly an arbitary one, the author preferred to accept the validity of both genera. This is the present attitude of the author.

Several species of *Brachythyris* have been described from the Lower Carboniferous faunas of Eastern Australia, and in the Cania district, both *Brachythyris* and *Martinia* occur. There seems little doubt that the Australian forms are closely interrelated.

Dunbar (1955, p. 151–152) considered the problem of the generotype of *Martinia*, caused through McCoy's figuring a broad form instead of the slender one originally identified by Martin (1809, pl. 48, figs. 9,10) as *Conchyliolithus Anomites glaber*. As Dunbar pointed out, Buckman recognized this possible source of confusion and selected the slender form identified by Martin as the "genolectotype" of *Martinia*. In view of this, Leidhold's erection of *Pseudomartinia*, using the slender form as generotype, was regarded by Dunbar (1955, p. 152) as invalid.

However, since *Conchiolithus anomites glaber* described by Martin (1809) is invalid under a ruling of the International Commission on Zoological Nomenclature (see Muir-Wood 1951, p. 97–118), and since the species has been referred to the next subsequent author, viz. *Spirifer glaber* Sowerby 1820, then the interpretation of the species will depend on Sowerby's original specimen. Muir-Wood (1951, p. 109–112, pl. 111, fig. 22-c) redescribed and figured this holotype, which is a broad form. Such being the case, part of Dunbar's reasoning, especially that concerned with *Pseudomartinia*, may not be valid, and should the slender forms of *Spirifer glaber* be recognized as a separate species, *Pseudomartinia* may be validated.

The type species, *Spirifer glaber* Sowerby was redescribed, figured and discussed by Muir-Wood (1951, p. 109–112, pl. 111, figs. 22-c). It occurs in beds of Lower Carboniferous age, in Derbyshire. George (1927) recorded species from the Viséan, $D_2$–$D_3$ zone in the Upper Limestone Shales of South Wales as well as unnamed species from the "Carboniferous Limestone of the Midlands and the north of England." In Belgium, *Martinia* has been described from Le Marbre Noir de Dinant by Delépine (1928, p. 31, pl. VI, fig. 79), who placed this formation at the base of the Viséan (Via zone of the Belgian sequence). Vaughan (1915, p. 1–52) preferred to accept the Marbre Noir de Dinant as transitional between Viséan and Tournaisian, and as such intermediate between the $C_2$–$S_1$ zones of the Avonian sequence.

The species described by Rotai (1931, p. 135, pl. IX, figs. 9–12) as *Spirifer implex* from the $C_1$ horizon of the Lower Carboniferous of the Donetz Basin, possibly belongs to *Martinia*. If this is its correct generic identity then *Martinia's* range extends down towards the base of the Tournaisian in Russia. Sarycheva and Sokolskaya (1952, p. 213–216, pl. 64, figs. 360–364), describe species of *Martinia* from the $C_1$, $C_2$ and $C_3$ zones of the Moscow Basin, i.e. from late Viséan to Upper Carboniferous. In North America, the genus has been described by Weller (1914, p. 420–422, pl. 75, figs. 1–4) from the Okaw Limestone, Chester Series, which Weller *et al.* (1948, p. 91–196) have correlated with the top of the Viséan in Europe.

*Martinia* occurs in beds of late Tournaisian—early Viséan age in Queensland, and in New South Wales it has been recorded from beds which Campbell (1959) believes to be of doubtful Lower Tournaisian age, but which were regarded by Delépine (1941) as Upper Tournaisian.

*Range.*—Except for the doubtful species in the early Tournaisian fauna of the Donetz Basin, *Martinia* seems to be characteristic of the late Tournaisian and Viséan.

MARTINIA NEOPRODUCTOIDES n. sp.
Pl. 19, figs. 12–14

*Holotype.*—F. 28607 University of Queensland Collection; from L1970, Portion 9, Parish Cannindah, County Yarrol, Queensland. Late Tournaisian.

*Diagnosis.*—Shell slightly elongate, strongly sinuate, moderately biconvex, non costate.

*Description.*—The ventral valve is longer than wide, moderately convex, with a prominent, incurved umbo. The area is small, curved and triangular. A strong median sinus extends anteriorly from the umbo. No median rib is developed in the sinus. The dorsal valve is less convex than the ventral and carries an undivided medial fold. Concentric growth lines are present, but no radial ornament is developed.

Internally, two strong teeth, at the corners of the delthyrium, are buttressed by two low carinae which border the delthyrium, under the area. True dental plates are not developed. The shell is much thickened in the umbonal region, and as a result the delthyrial cavity is small. The floor of the delthyrial cavity contains the muscle impression which is rhomboidal and striated. The dorsal valve contains a small cardinal process situated between the crural bases. No median septum or ridge is developed.

*Dimensions of Holotype.*

| | *Ventral Valve* | *Dorsal Valve* |
|---|---|---|
| Length | 37 | 30 |
| Width | 35 | 35 |

*Remarks.*—*M. neoproductoides* is similar to *M. productoides* Etheridge of which the type specimens were found at Cania, 30 miles north of Old Cannindah. However, Etheridge's species is more elongated and less sinuate than *M. neoproductoides*, and is readily distinguished by these differences.

The species from the Rangari limestone in northern New South Wales is generally smaller than the Cannindah form and has noticeable costation.

Of the European forms. *M. neoproductoides* is probably most similar to those described and figured by Davidson (1858, p. 255, pl. XII, figs. 9,10) as *Spirifera glabra* from the Lower Carboniferous of Lowick and Yorkshire in England. *Martinia glabra* figured by Delépine (1928, pl. VI, fig. 1) from the early Viséan of Belgium, is an incomplete specimen, and is probably a wider form than *M. neoproductoides*. *Martinia glabra* from the late Viséan and Namurian of the Moscow Basin, described by Sarycheva and Sokolskaya (1952, p. 215, pl. 64, fig. 361) is also broader, but is the most similar of the Moscow species. *M. hemisphaerica* Ainor (1957, p. 153–154, pl. 3, fig. 1) from the Central Urals Lower Carboniferous faunas, is somewhat similar.

The American species *M. contracta* Meek and Worthen and *M. sulcata* Weller from the Chester group are shorter, slightly broader forms.

No similar species have been figured from the Carboniferous of Japan.

Grabau (1954) records species of *Martinia* from Northern Persia (p. 224), Turkestan (p. 225), Sinkiang Province (p. 228), Szechuan, South China (p. 249), West Kansu, Central China (p. 252). Figures of species from these regions were not available for comparison with the Queensland form.

Subfamily BRACHYTHYRINAE Fredericks 1926

Genus BRACHYTHYRIS McCoy 1844

*Brachythyris* McCoy, p. 128. Buckman, 1908, p. 30; George, 1927, p. 106–119; *Ovalia*, Nalivkin, 1937, p. 107; *Brachythyris*, McCoy; Maxwell, 1954, p. 26–27.

*Generotype.*—(by original designation) *Spirifer ovalis* Phillips 1836, p. 219, pl. 10, fig. 5; from Bolland, Yorkshire. Lower Carboniferous.

*Diagnosis.*—Hinge line shorter than maximum width of shell; area small, curved, triangular; radially plicate, plications broad and flat on lateral slopes, deficient on fold; no dental plates developed.

*Remarks.*—The genus has been discussed at length in a previous paper (Maxwell, 1954).

*Range.*—*Brachythyris* McCoy is restricted to the Lower Carboniferous.

BRACHYTHYRIS sp. cf. B. DAVIDIS
(Dun, 1904)
Pl. 19, figs. 8–11

Cf. *Spirifer davidis* Dun, 1904, p. 323–324; pl. 60,

figs. 1, 1a–f. *Brachythyris* cf. *davidis;* Maxwell, 1954, p. 39, pl. 4, figs. 11,12.

*Locality.*—L 1970, Portion 91, Parish Cannindah.

*Description.*—Incomplete material prevents detailed description of this form. It possesses a strongly convex ventral valve, which is equidimensional. Maximum width occurs near the hinge line; the cardinal extremities are rounded. The ornament consists of broad plications, which widen anteriorly. A moderately developed median sinus is present, and it generally carries two plications. The ventral area is comparatively high, curved and triangular. The dorsal valve is weakly convex, and has a median fold.

Internally, there are two strong teeth, but no dental plates. Muscle scars are weakly impressed and poorly defined. No median plates are present.

*Dimensions.*—

| | *Ventral valve* |
|---|---|
| Length | 29 mm. |
| Width | 31 mm. |
| No. of plications | 22 |

*Remarks.*—This form resembles the one described from Mt. Morgan (Maxwell 1954, p. 39, pls. 11,12), in proportions, shape and ornament, but is about one and a half times the size. The Mt. Morgan species occurs in the late Tournaisian *Schizophoria* zone. It has been compared with *B. willbourni* Muir-Wood from the Viséan faunas of Malaya. *B. pseudovalis* Campbell (1957, p. 76–78, pl. 14, figs. 10–15) from Watts, Babbinboon, New South Wales, is more strongly plicate, more transverse and generally larger than the species from Old Cannindah.

BRACHYTHYRIS sp. indet.
Pl. 19, figs. 7a,b

*Locality.*—L1963, west of Old Cannindah Homestead, Parish Cannindah, County Yarrol.

*Description.*—Two incomplete specimens of this form were found. The ventral valve is comparatively large, strongly convex, sinuate and equidimensional. Maximum width occurs near the hinge line. The cardinal area is high and curved. Costae are somewhat flat and not well developed.

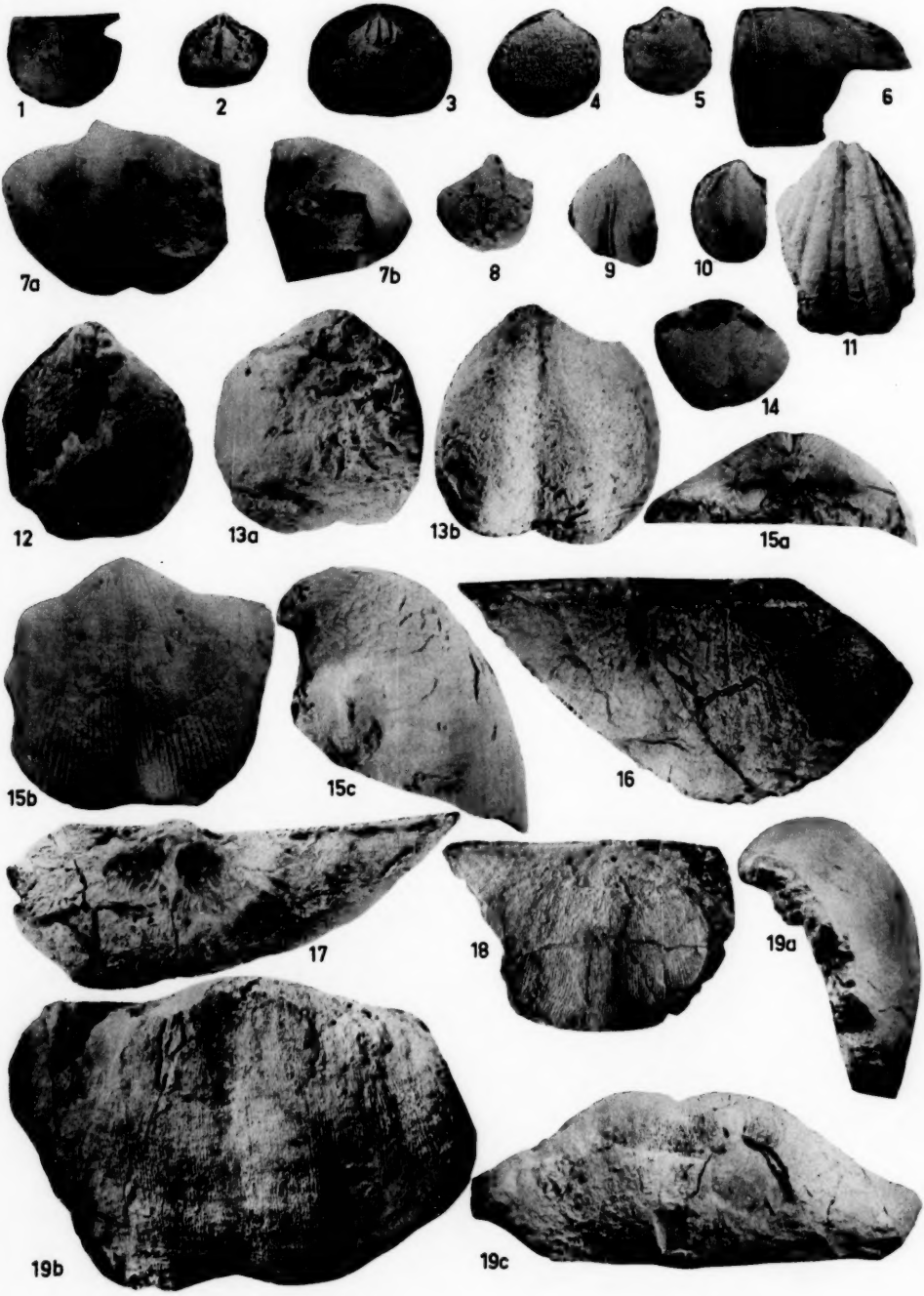
Internal characters are not known.

*Remarks.*—This species is similar in shape, dimensions and ornament to the form from the Viséan faunas of Mt. Morgan, described as *Brachythyris* cf. *pinguis* Maxwell (1954, p. 45, pl. 5, figs. 14–16). Affinities with

EXPLANATION OF PLATE 19

All figures natural size

FIG. *1*—*Rugosochonetes kennedyensis var. magnus* Maxwell. Internal mould of ventral valve, F28585.
*2–6*—*Rhipidomella australis* (McCoy). *2*—internal mould, dorsal valve, F28652. *3*—internal mould, ventral valve, F28653. *4*—decorticated dorsal valve, F28654. *5*—external of dorsal valve, F28651. *6*—latex impression of external ventral valve, F28609.
*7a,b*—*Brachythyris* sp. indet. *7a*—ventral view of ventral valve. *7b*—lateral view same specimen, F28663.
*8–11*—*Brachythyris* cf. *B. davidis* (Dun). *8*—internal mould, ventral valve, F28603. *9*—internal mould of ventral valve, F28602a. *10*—latex impression of external of ventral valve, F28604. *11*—external of ventral valve, F28605.
*12–14*—*Martinia neoproductoides* n. sp. *12*—ventral view of partly decorticated valve, showing shell shape and part of muscle field, F28608. *13a*—dorsal view of holotype, F28607. *13b*—ventral view of holotype. *14*—ventral view of posterior part of shell, F28608.
*15a–c*—*Ectochoristites wattsi* Campbell. *15a*—ventral view of ventral valve, F28601. *15b*—lateral view of same specimen. *15c*—posterior view showing cardinal area.
*16–19*—*Daviesiella cannindahensis* n. sp. *16*—partly decorticated ventral valve, F28658. *17*—internal of dorsal valve showing thickened cardinal process and muscle scars, F28660. *18*—dorsal valve, external, F28656. *19a*—lateral view showing profile of holotype, F28655. *19b*—ventral view of holotype. *19c*—posterior view of holotype.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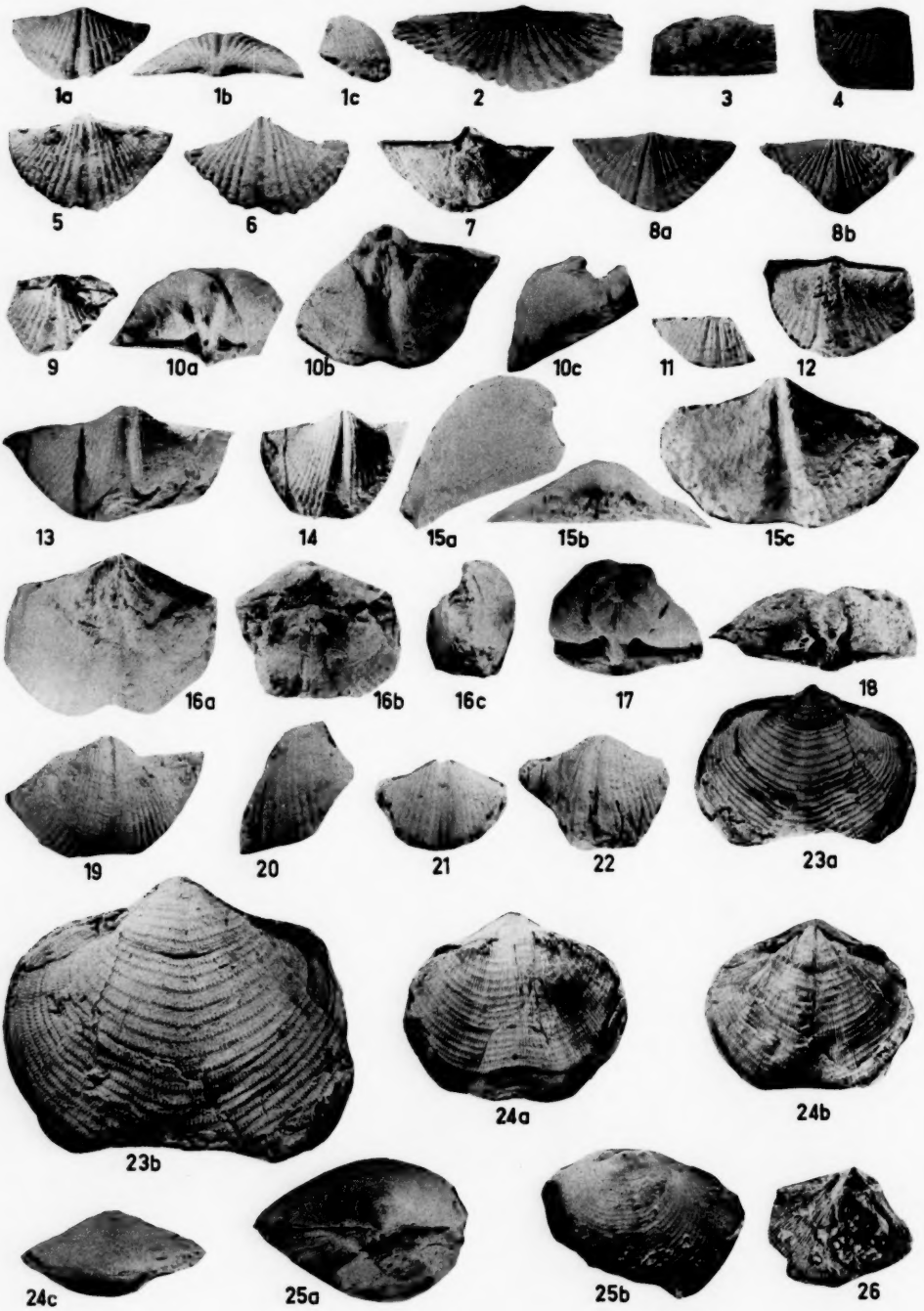
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foreign species are difficult to recognize. At Old Cannindah, this form occurs in the reef core (Viséan $D_1$–$D_2$ age), where it is associated with a predominantly coralline fauna.

### Subfamily PHRICODOTHYRINAE Caster 1939.

*Remarks.*—Caster (1939, p. 144–145) erected the sub-family Phricodothyrinae to include those reticularioid spiriferids with biramous spine bases, viz. *Phricodothyris* George 1932 and *Squamularia* Gemmellaro 1899. In so doing, he separated this group from Reticulariinae Waagen 1883, which he restricted to forms with uniramous spine bases. More recently, Minato (1953, p. 65–73) reviewed the reticulate spiriferids, regrouped them all under Reticulariinae Waagen, and proposed a key to genera based on ornament and internal plates. He erected five new genera, bringing the total number to eleven, viz: *Squamularia* Gemmellaro 1899, *Reticularia* McCoy 1844, *Georgethyris* Minato 1953, *Sinothyris* Minato 1953, *Torynifer* Hall and Clarke 1895, *Kitakamithyris* Minato 1951, *Phricodothyris* George 1932, *Martinothyris*, Minato 1953, *Spirelytha* Fredericks 1919, *Condrathyris* Minato 1953 and *Nebenothyris* Minato 1953. Minato's genera were separated from existing genera on differences in the development of dental and crural plates, and median septa.

George (1932, p. 524) recognized the variability in the internal structure of the group, but emphasized that while such marked internal differences did exist, they were not sufficiently consistent to serve as a basis for generic differentiation. He accepted ornament as a more significant character and relying on that, restricted the number of genera to four—*Reticularia*, *Phricodothyris*, *Squamularia*, *Spirelytha*—the first having uniramous spine bases, the latter three having biramous spines. George did not consider *Torynifer* Hall and Clarke, but

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EXPLANATION OF PLATE 20

Figures natural size except where indicated otherwise

FIGS. *1–7*—*Prospira burnettensis* n. sp. *1a*—ventral view of holotype F28586. *1b*—posterior view of holotype ×1.3. *1c*—lateral view, showing profile of holotype. *2*—external of ventral valve F28591. *3*—posterior view of etched specimen showing thickened dental plates F28587. *4*—latex impression of dorsal external F28592. *5*—ventral valve F28589. *6*—ventral valve, partly decorticated F28590a. *7*—posterior view of internal mould of ventral valve with dental plates preserved F28588.

*8,9*—*Prospira prima* Maxwell (from Mt. Morgan, Queensland). *8a*—internal mould of dorsal external valve, holotype F15244a. *8b*—latex impression of dorsal valve, holotype F15244b. *9*—internal mould of ventral valve F15246.

*10–14*—*Prospira typa* Maxwell (from Mt. Morgan, Queensland). *10a*—internal impression of ventral valve, posterior view, holotype F15251. *10b*—ventral view, holotype. *10c*—lateral view, holotype. *11*—latex impression of external of dorsal valve topotype F15252. *12*—Internal mould of dorsal valve, topotype F15261. *13*—Latex impression of ventral external, topotype F15250. *14*—latex impression of ventral external, topotype, F15253.

*15–22*—*Prospira typa var. tellebangensis n. var. 15a*—lateral view ventral valve, F28593. *15b*—posterior view. *15c*—ventral view. *16a*—ventral view of holotype, F28594. *16b*—dorsal view. *16c*—lateral view. *17*—internal mould ventral valve, posterior view, F28596. *18*—internal mould, ventral valve, posterior view, F28595a. *19*—latex impression of ventral external, F28597. *20*—Latex impression of sinus right slope of ventral valve, F28598. *21*—latex impression of ventral external, F28599. *22*—latex impression of ventral external, F28600.

*23,24*—*Kitakamithyris uniplicata* (Campbell). *23a*—External mould of ventral valve holotype F28661b. *23b*—latex impression of F28661b, showing spine bases and fine radial lirae. ×2. *24a*—internal mould, ventral valve, holotype F28661a. *24b*—dorsal view. *24c*—anterior view.

*25,26*—*Kitakamithyris globosa* n. sp. *25a*—posterior view, holotype, F28662. *25b*—dorsal view holotype. *26*—internal of dorsal valve showing cardinal structures, F28650.

it too belongs to the group with biramous spines.

Minato (1953) was less restrained than George in generic differentiation, and after recognizing the primary division into uniramous and biramous types, he attempted to subdivide these on the nature of the internal plates. The value of such differentiation may be questioned on several points. Firstly, as George (1932, p. 524) indicated, the wide range of ventral internal variation in specimens from the one locality would suggest that complete gradation existed from aseptate to septate forms, thus rendering any such division artificial. Secondly, the presence or absence of "socket plates" in the dorsal valve would appear to depend on the state of preservation of the specimen and the techniques used in its preparation. It is doubtful whether any member of the group is without crural plates (socket plates of Minato)—their minute size can result in their non-recognition. The third internal structure used by Minato is the dorsal median septum—present in *Martinothyris Torynifer* and *Nebenothyris*. Here again, it is doubtful whether any of the reticulate spiriferids is without an incipient median ridge or septum—the taxonomic value of which is a matter of personal opinion. The writer prefers a more conservative attitude than that of Minato, and believes that the internal characters of this group should be used more cautiously. Surface ornament might be approached with the same caution. Although the major division into Reticulariinae and Phricodothyrinae, based on the nature of the spine bases, appears to be sound, generic sub-division based on characters such as the density of spine distribution, random or radial arrangement of spines presence or absence of interspinous pustules, is hardly supported by the results of George's studies. In all the species described by George (1932) both *Phricodothyris* and *Reticularia* showed spine densities ranging from 8 to 40 per 10 mm. near the anterior margins (*R. alexandri* had 90–100 per 10 mm.); some spine bases were radially arranged; none of the described species had interspinous pustules, although George had recognized these on other material.

In addition to the possibility that some of the new genera proposed by Minato may be founded on characters of doubtful taxonomic value, at least two of the genera are invalid because of incorrect designation of the type species while another may not belong to this group of spiriferids. The generotype of *Martinothyris* Minato (1953, p. 70) was cited as "*Phricodothyris lineata* (Martin) 1932 @ George," and more specifically as "the specimen on page 545 (George 1932)," which shows dental plates in the ventral valve and socket plates in the dorsal valve. Two points arise in relation to this genus. Firstly, George (1932) selected a neotype for *Phricodothyris lineata* (Martin). However, Muir-Wood (1951, p. 105–106), in accordance with the decision of the International Commission on Zoological Nomenclature, which ruled that species described by Martin (1793 and 1809) were invalid, referred thirteen of Martin's species to subsequent author's, and the species "*Conchylio-lithus Anomites* (*lineatus*)" was referred to Sowerby 1822 who described it as *Spirifer lineatus*. Muir-Wood selected one of Sowerby's syntypes as the lectotype and re-figured and described it. This specimen, which has priority over George's suggested neotype, has no dental plates, and is similar in all its characters to *Phricodothyris lucerna*, George, the generotype of *Phricodothyris*. In view of this, *Phricodothyris lineata* (Sowerby) can hardly be separated from *Phricodothyris* and consequently *Martinithyris* becomes a synonym of that genus. The second point to be noted is that Minato stated "The writer selects this specimen as the genotype," the specimen being that figured by George (1932, p. 545), showing dental plates. This is contrary to the rules of nomenclature, since a generotype must be a species. Therefore, in order to separate forms which have dental plates, separation must first be made at the species level.

*Nebenothyris* Minato 1953, is the second name invalidated under the rules of nomenclature, since the proposed generotype "*Spirifer lineatus* Nebe non. Martin" is not a valid species, and would have to be redefined and renamed before becoming available.

*Georgethyris* Minato 1953, with generotype *Reticularia alexandri* George 1932 was separated from *Reticularia* on the basis of its diverging dental plates and absence of a

ventral median septum. In the British species described by George the angle of divergence of the dental plates ranges from a few degrees to 35°, but for most species is approximately 20°. In the holotype of *Reticularia imbricata*, the generotype of *Reticularia*, the angle of divergence is not known. Other members of this species have subparallel plates according to George (1932, p. 559). The presence or absence of a median septum in *Reticularia alexandri* has not been ascertained on the holotype, and further it is so variable in other species that it should be regarded as of doubtful value. There seems good reason for referring *Georgethyris* to the synonymy of *Reticularia*.

*Condrathyris* Minato 1953, with generotype *Spirifer perplexa* McChesney 1860, has the same internal structures as *Phricodothyris*, and very similar ornament. Dunbar and Condra (1932, p. 311, 319) in redescribing Chesney's species, figured the ornament. Their diagram showed two types of spines—a larger series rising from biramous bases and a smaller series whose bases could possibly correspond to the interspinous pustules mentioned by George in *Phricodothyris*. However, the spines of the American species, as illustrated by Dunbar and Condra do not develop the double hooklets found in *Phricodothyris*. It is possible that this difference may be due to preservation.

*Sinothyris* Minato 1953, with generotype *Spirifer maureri* Holzapfel 1895, does not appear to have the same ornament as other members of the Reticulariinae and Phricodothyrinae, but fine radial lirae, producing serrations at the margins of the growth lamellae. This genus could well be ancestral to the Carboniferous forms, but on present evidence, it is doubtful whether the genus should be referred to these subfamilies.

Subfamily RETICULARIINAE
Waagen—Uniramous
spine bases.

1. *Squamularia* Gemmellaro 1899; generotype *Squamularia rotundata* Gemmellaro 1899. Permian. Without dental plates.
2. *Reticularia* McCoy 1844 (=*Georgethyris* Minato 1953); generotype *Terebratula imbricata* Sowerby 1822. Lower Carboniferous. With dental plates; low ventral median septum present or absent.

Subfamily PHRICODOTHYRINAE
Caster—biramous
spine bases.

1. *Phricodothyris* George 1932 (=*Martinothyris* Minato 1953, *Nebenothyris* Minato 1953, *Condrathyris* Minato 1953); generotype *Phricodothyris lucerna* George 1932. Carboniferous; without dental plates and median septum; sometimes with interspinous pustules.
2. *Kitakamithyris* Minato 1951; generotype *Kitakamithyris tyoanjiensis* Minato 1951. Carboniferous. With strong dental plates and median septum; no interspinous pustules. Spine bases radially distributed.
3. *Torynifer* Hall and Clarke 1895; generotype *Torynifer criticus* Hall and Clarke 1895; Lower Carboniferous. With strong dental plates, and dorsal hinge plate supported on median septum; no interspinous pustules.

Genus KITAKAMITHYRIS Minato 1951

*Kitakamithyris* Minato, 1951, p. 374–376, pl. 1, figs. 1,3; pl. 4, fig. 7; Minato 1952, p. 170–172, pl. 6, figs. 5; pl. 7; figs. 3,6; pl. 8, figs. 5,6,8; pl. 9, fig. 4; pl. 10, figs. 2,3; Minato 1953, p. 71.

*Generotype.*—(by original designation) *Kitakamithyris tyoanjiensis* Minato 1951, p. 374–375, pl. 1, figs. 3a–b, pl. 4, fig. 7; from the Hikoroiti series, Tyoanji, Hikoroitimura, North East Honsyu, Japan; Lower Carboniferous.

*Diagnosis.*—Brachythyrid shell form; lamellose-spinose ornament, spines biramous, radially distributed; no interspinous pustules; shell impunctate; strong dental plates; variable median septum in ventral valve.

*Remarks.*—*Kitakamithyris* is most closely allied with *Phricodothyris* and is distinguished from this genus on three characters, which are of somewhat doubtful generic value. The first two are ornament—in *Kitakamithyris* the spine bases have approximately the same density as those of *Phricodothyris* (±25 per 10 mm.), but the individual bases are generally larger so that

interspinous surface is less. No interspinous pustules have been recorded. The second difference is in spine distribution. Although Minato did not consider this in his original diagnosis, his figures reflect the radial distribution of spines, and in the Queensland species, this radial arrangement is emphasized by the development of lirae. The third difference is internal—the ventral valve always has two dental plates and a long median septum of variable height.

George (1932) recognized the variability in the internal structures of the British phricodothyrids, and rightly refused to subdivide the group on the basis of such structures. However, in Japan and Eastern Australia, all the species so far recorded show remarkable constancy in their development of dental plates and septum. In view of this, it seems reasonable to accept *Kitakamithyris* as a separate genus.

In Japan, the genus has been found in the Arisu and Hikoroiti formations (Minato 1951, 1952; Yabe 1958) of Tournaisian age. At Yarrol, in Queensland it ranges from the middle of the Baywulla Formation through the Branch Creek and into the Poperima Formation—these are of Viséan, Namurian and Middle Carboniferous ages respectively. Campbell (1955, p. 373–384) described four species from the Upper Tournaisian and Viséan of New South Wales, and has also recorded it from the Middle Carboniferous (pers. comm.).

The genus has a wide range—basal Tournaisian into Middle Carboniferous, but specific differentiation has made it a useful stratigraphic fossil.

KITAKAMITHYRIS UNIPLICATA
(Campbell 1955)
Pl. 20, figs. 23–24

*Phricodothyris uniplicata* Campbell 1955, p. 377–379, pl. 18, figs. 1–9.

*Holotype.*—F. 1340 University of New England Collection; from L35, Babbinboon, grid reference 570–637 Attunga one mile military map; top of Lower Burindi Group; Upper Tournaisian. Specimens figured in this paper from L1970, Portion 91, Parish Cannindah.

*Diagnosis.*—Transverse, uniplicate shell; high concave area; pointed, incurved ventral umbo; strong concentric lamellae, 9–15, per 10 mm.; biramous spine bases, 32–40 per 10 mm.; strong dental plates, long median septum in ventral valve; faint median ridge in dorsal valve.

*Description.*—The shell is moderately biconvex, approximately three quarters as long as wide, with rounded cardinal extremities. Maximum width is 8–10 mm. anterior to the hinge. The ventral umbo is incurved over a moderately high, curved area. A shallow median sinus extends anteriorly to the uniplicate commissure. A corresponding low fold occurs on the brachial valve. The ornament consists of regularly spaced lamellae—(10 per 10 mm.), each carrying biramous spine bases (35 per 10 mm. anteriorly) which rise from small lirae and consequently have a radial distribution. These fine lirae are reflections of well-defined, minute, radial grooves which cover the entire internal surface of the shell.

Two strong dental plates, diverging at 35–40°, extend anteriorly for 9 mm., i.e. approximately one third of the shell length. The median septum, 15 mm. in length, extends for more than half the shell. A low median ridge extends for the same distance in the dorsal valve.

*Dimensions of Queensland Form.*—

| | *Length* | *Width* | *Width at Hinge* | *Septum* | *Dental plates* | *Angle of plates* |
|---|---|---|---|---|---|---|
| Ventral Valve | 27 | 38 | 24 | 15 | 8 | 35 |
| Dorsal Valve | 27 | 33 | 24 | 12 | | |

*Remarks.*—The diagnostic features of the Queensland form are the fine lirae giving rise to spine bases at their intersection with growth lamellae, the deep radial grooves on the internal surface, and the uniplication of the shell. In his description of *Kitakamithyris uniplicata*, Campbell (1955, p. 377–379) concentrated on external proportions and shell shape, and paid less attention to details of ornament. However, material

TEXT-FIG. 2—Serial sections through umbonal region of *Kitakamithyris globosa*. Sections at 1.5 mm. intervals.

from New South Wales examined by the author reveals the same ornament as that of the Queensland species.

The species described from Mt. Morgan as *Phricodothyris lineata*, (Maxwell, 1954, p. 37–39, pl. IV, figs. 9–10) differs from *Kitakamithyris uniplicata* in its more globose shape, less lirate ornament, and smaller internal plates.

*Kitakamithyris* has a comparatively long range in Eastern Australia (Tournaisian—Moscovian) and at least four taxonomic units have been recognized within the genus. Although these units have been assigned specific rank, primarily for stratigraphic reasons, the gradational variation within the genus renders subdivision somewhat arbitrary. Breaks in the faunal record have encouraged the splitting of the genus, but as more new faunas are discovered, specific boundaries become less clearly defined.

In New South Wales it occurs in beds of late Tournaisian age (Campbell 1955, p. 379), and in Queensland it is associated with fauna of similar age.

### KITAKAMITHYRIS GLOBOSA, n. sp.
Pl. 20, figs. 25–26

*Holotype.*—F 28662, University of Queensland Collection; from L1963, west of Old Cannindah Homestead, Parish Cannindah, County Yarrol, Queensland; Viséan.

*Diagnosis.*—Strongly biconvex, weakly uniplicate, transverse to equidimensional shell; ornament of concentric, closely spaced lamellae, fine lirae and biramous spines; ventral valve with short dental plates, low median septum; dorsal valve with strong crural plates, large hinge plate, no septum; internal surface radially grooved.

*Description.*—This species is characterized by its strong biconvexity, incipient uniplication, and equal dimensions. In outline, the valves are subcircular, with maximum width approximately 10 mm. anterior to the hinge. A shallow median sinus becomes evident near the anterior margin. The ventral umbo is high, pointed and incurved over a high, curved triangular area which is marked by transverse lines which are continuous with the growth lamellae. The delthyrium is open. The ornament consists of closely spaced lamellae (14 per 10 mm.), interrupted by fine lirae which give rise to biramous spines at their intersections with the lamellae.

The dental plates are short, subparallel structures extending along the valve floor for less than one third of the length of the valve. The median septum is a low ridge, less than 2 mm. in height. No median ridge is apparent in the dorsal valve. However, crural plates and a transverse hinge plate are strongly developed.

*Dimensions.*—

| Ventral Length | Ventral Width | Dorsal Length | Dorsal Width | Thickness | Hinge Width |
|---|---|---|---|---|---|
| 34 | 35 | 32 | 35 | 22 | 26 |
| >30 | 40 | >30 | 40 | 23 | — |
| >30 | 40 | >30 | 40 | >20 | 27 |

*Remarks.*—*Kitakamithyris globosa* is characterized by its strong biconvexity and is readily distinguished from other Queensland species. It occurs in the reef core of the limestones as Old Cannindah, where it is associated with a fauna of Viséan ($D_1$–$D_2$) age.

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# DRESBACHIAN AND FRANCONIAN TRILOBITES OF THE CONOCOCHEAGUE AND FREDERICK LIMESTONES OF THE CENTRAL APPALACHIANS

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ABSTRACT—This paper includes (1) Additions to the Franconian *Elvinia* zone fauna from the Conococheague formation in Virginia. (2) Description of a faunule of the Dresbachian *Crepicephalus* zone from the same formation and area. (3) Description of a faunule of the *Dunderbergia* zone, the first recognized in eastern North America, from the basal Frederick limestone of Maryland. The occurrence of trilobites of the *Dunderbergia* zone in exotic boulders in the Lower Ordovician of Quebec is also discussed. Systematic descriptions include three new trilobite genera: *Bathyholcus* (type, *B. gaspensis*, n. sp.); *Glyptometopsis* (type, *G. tumida*, n. sp.); and *Taenicephalites* (type, *T. macrops*, n. sp.). Other described new species are: *Bathyholcus sulcatus, Blountia virginica, Dunderbergia simplex, Glaphyraspis ovata, Glyptometopsis? marginata, Komaspidella laevis, K. lata, Llanoaspis convexifrons, Meteoraspis mutica, Quebecaspis marylandica, Q. conifrons.*

## INTRODUCTION

IN A previous paper (Rasetti, 1959) the author discussed the fossils of Trempealeauian age from the limestones of the Cumberland-Shenandoah valleys of Pennsylvania, Maryland and Virginia and the Frederick valley of Maryland. Faunas of Dresbachian and Franconian ages were known to occur in the Conococheague limestone (Wilson, 1952). Additions to the fauna of the *Elvinia* zone and a faunule of the *Crepicephalus* zone are described herein. However, the most significant contribution to Cambrian biostratigraphy here presented is the discovery of a faunule of the *Dunderbergia* zone in or near the lower portion of the Frederick limestone. The fauna of the *Dunderbergia* zone had not so far been recognized in eastern North America. Furthermore, it occurs in a limestone that had

## EXPLANATION OF PLATE 21

All the figured specimens are from the *Crepicephalus* zone of the lower Conococheague formation near Winchester, Va. (localities cce, ccf).

FIGS. *1–5,8—Blountia virginica* Rasetti, n. sp. *2,3*, Lateral and dorsal views of small cranidium preserving test, ×5 (USNM 143060, holotype). *1*, Cranidium preserving test, ×3. *4*, Pygidium preserving test, ×3. *5*, Exfoliated pygidium, ×3. *8*, Free cheek preserving test, ×5 (USNM 143061, paratypes).

*6,7,9–11—Komaspidella laevis* Rasetti, n. sp. (all specimens preserving test, ×5). *6,7*, Dorsal and lateral views of cranidium (USNM 143079, holotype). *9*, Pygidium. *10,11*, Dorsal and lateral views of pygidium (USNM 143080, paratypes).

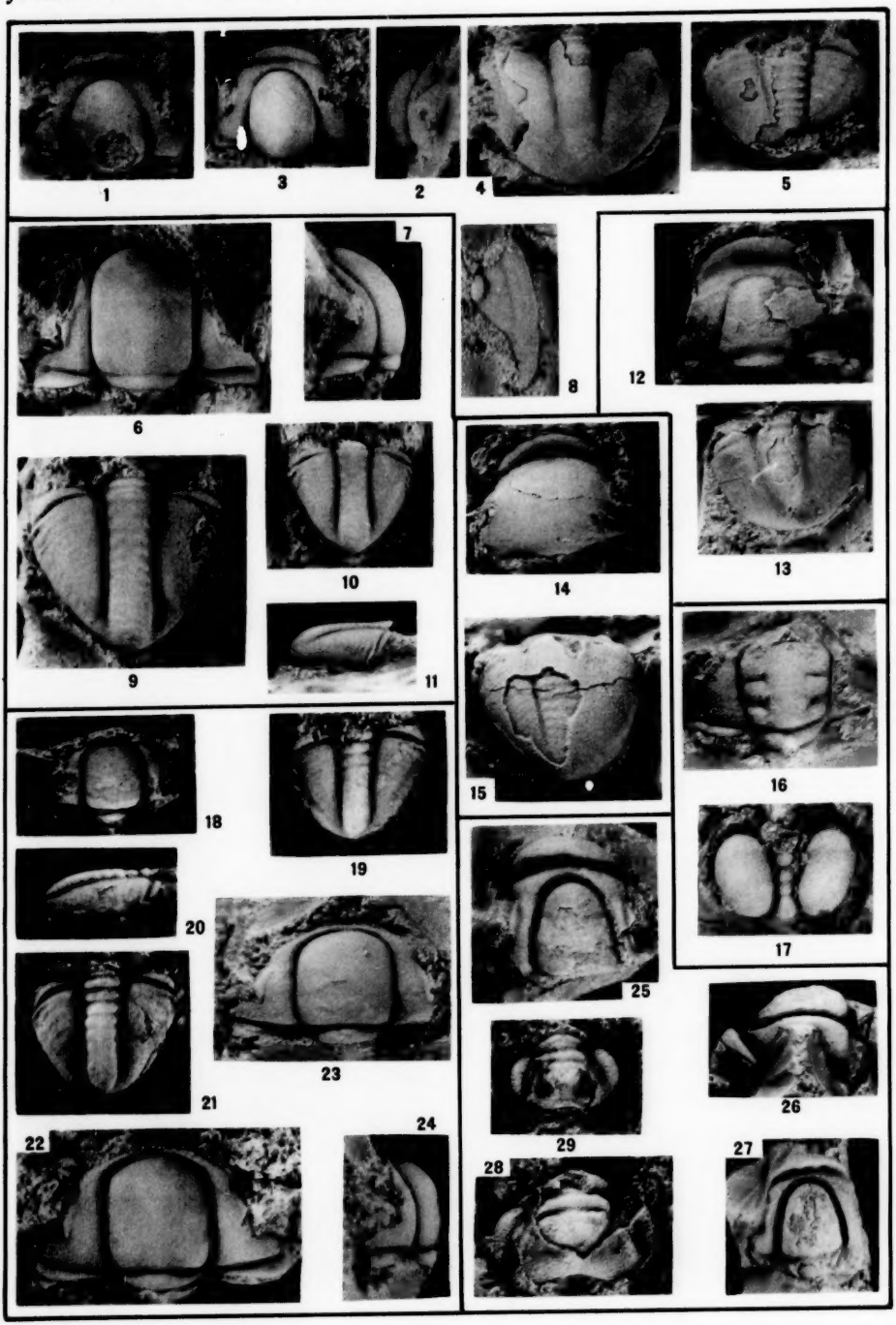
*12,13—Coosina ariston* (Walcott). *12*, Exfoliated cranidium, ×2. *13*, Pygidium preserving test, ×3 (USNM 143063, plesiotypes).

*14,15—Marywillia arion* Walcott, ×3. *14*, Cranidium preserving test. *15*, Partly exfoliated pygidium (USNM 143083, plesiotypes).

*16,17—Pemphigaspis*, sp. undet., ×8. *16*, Cranidium preserving test. *17*, Pygidium preserving test (USNM 143086).

*18–24—Komaspidella lata* Rasetti, n. sp. (all specimens preserving test). *22*, Cranidium, ×8 (USNM 143077, holotype). *18*, Cranidium, ×5. *19*, Pygidium, ×5. *20,21*, Lateral and dorsal views of pygidium, ×5. *23,24*, Dorsal and lateral views of cranidium, ×5 (USNM 143078, paratypes).

*25–29—Meteoraspis mutica* Rasetti, n. sp. *29*, Pygidium preserving test, ×8 (USNM 143084, holotype). *25*, Small cranidium preserving test, ×5. *26,27*, Dorsal and lateral views of exfoliated cranidium, ×3. *28*, Partly exfoliated pygidium, ×8 (USNM 143085, paratypes).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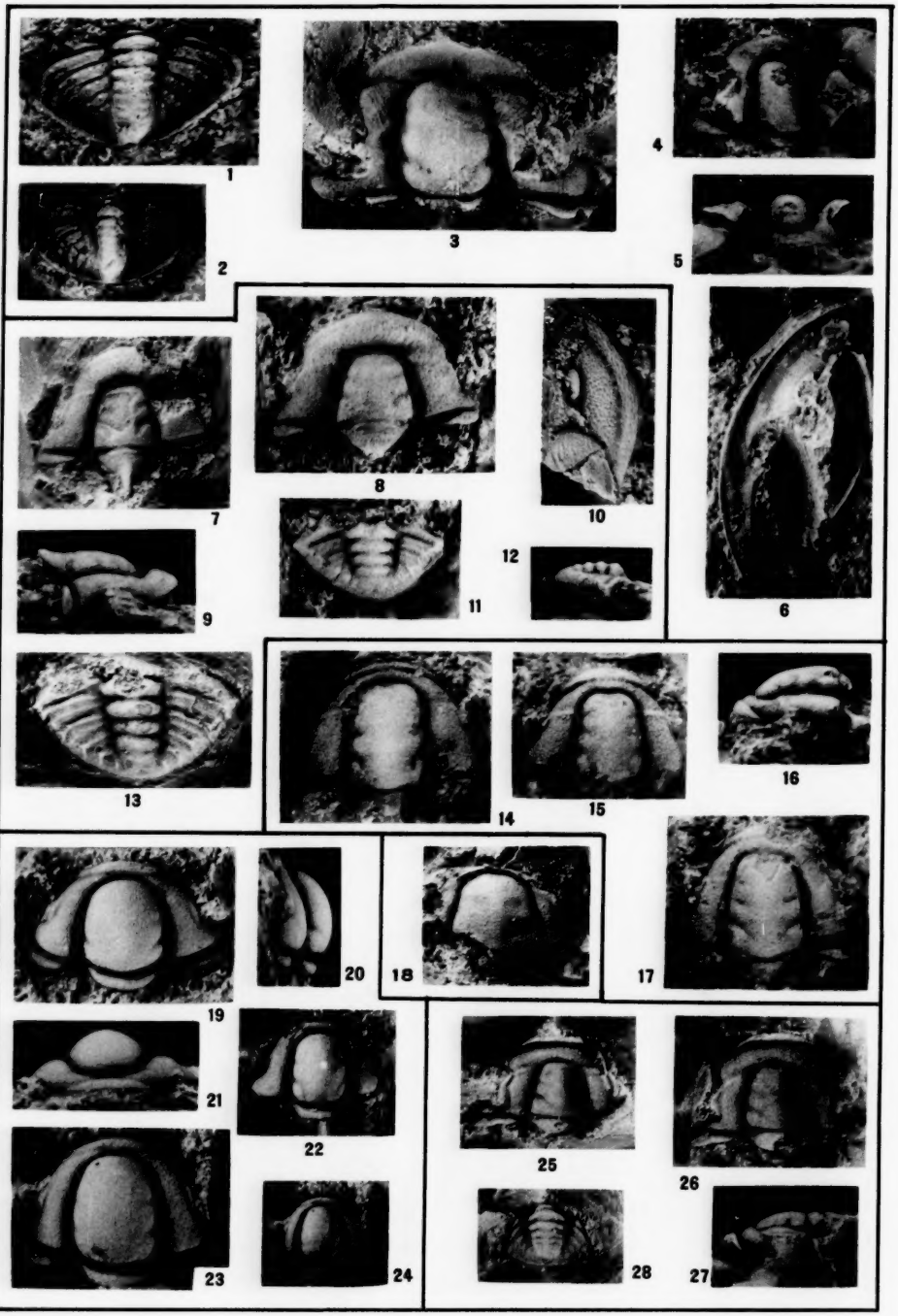
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been mapped as Lower Ordovician Grove limestone, thus suggesting revision of the stratigraphy of the Frederick Valley.

Localities discussed are indicated by abscissa and ordinate in millimeters on the U.S. Geological Survey topographic maps.

All the described fossils were deposited in the U.S. National Museum collections.

The writer is indebted to Dr. A. R. Palmer for information concerning the distribution of Upper Cambrian faunas in the western sections and for examining the fossils and some of the exposures. He is also grateful to the Penrose Bequest of The Geological Society of America for a grant.

## STRATIGRAPHY AND FAUNAS

*Conococheague formation.*—Information concerning the stratigraphy is given by Wilson (1951, 1952). Trilobites of Franconian age (*Elvinia* zone) were found by Wilson at several localities in Maryland and Virginia, where a characteristic assemblage designated the *Pseudosaratogia magna* faunule occurs. The author collected material of this faunule at two localities. The first, the author's locality ccd, presumably coincides with Wilson's locality 45-lw-2 and is in the southern suburbs of Winchester, Va. ($x = 87$, $y = 293$, Winchester 15-minute quadrangle, scale 1:32,500). The other, the author's locality ccc, is in the western suburbs of Winchester. Here most of the collecting was done from loose blocks, which might have come from any of several fossiliferous horizons indicated by Wilson as 45-lw. However, the distinction is of little importance since Wilson gave essentially the same faunal list for all. The location is $x = 88$, $y = 337$, Winchester quadrangle.

It seemed unnecessary to reillustrate the species that were figured by Wilson. Only two additional species are described herein. Adding these to Wilson's list, the *Pseudosaratogia magna* faunule of the Conococheague formation includes the following species:

*Buttsia drabensis* Wilson
*Cheilocephalus*, sp. undet.
*Dellea saratogensis* Wilson
*Drabia curtoccipita* Wilson
*Eshelmania convexa* Wilson
*Eshelmania snoburgensis* Wilson
*Glaphyraspis ovata* Rasetti, n. sp.
*Pseudosaratogia magna* Wilson

The occurrence of various Dresbachian genera in the lower portion of the Conococheague was mentioned by Wilson (1952, p. 305), but no descriptions were given. Therefore it seems worthwhile to describe a well-preserved trilobite faunule collected from the Conococheague in the vicinity of Winchester, Va. The locality (ccf) is on the north slope of a low hill south of US Route 50 ($x = 83$, $y = 334$, Winchester quadrangle). The fossiliferous beds are 50–60 feet below the base of the lowest sandstone member of the Conococheague formation. Since the

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EXPLANATION OF PLATE 22

All the figured specimens are from the Conococheague formation near Winchester, Va. Figs. 1–17 represent the fauna of the *Crepicephalus* zone (localities cce, ccf); figs. 18–28 the fauna of the *Elvinia* zone (localities ccc, ccd). The test is preserved in all figured specimens.

FIGS. *1–6—Llanoaspis convexifrons* Rasetti, n. sp. *3*, Cranidium, ×5 (USNM 143081, holotype). *1,2*, Pygidia, ×5. *4,5*, Dorsal and frontal views of cranidium, ×5. *6*, Free cheek, ×4 (USNM 143082, paratypes).

*7–13—Terranovella dorsalis* (Hall). *7*, Cranidium, ×8. *8,9*, Dorsal and lateral views of cranidium, ×8. *10*, Free cheek, ×8. *11,12*, Dorsal and lateral views of pygidium, ×8. *13*, large pygidium, ×5 (USNM 143098, plesiotypes).

*14–17—Glaphyraspis parva* (Walcott), ×12. *14,17*, Cranidia. *15,16*, Dorsal and lateral views of cranidium (USNM 143069, plesiotypes).

*18—Cheilocephalus*, sp. undet. Cranidium, ×5 (USNM 143062).

*19–24—Glaphyraspis ovata* Rasetti, n. sp. *19–21*, Dorsal, lateral, and frontal views of cranidium, ×10 (USNM 143070, holotype). *22*, Cranidium, ×10. *23,24*, Another cranidium, ×10 and ×5 (USNM 143071, paratypes).

*25–28—Drabia curtoccipita* Wilson, ×5. *25,27*, Dorsal and lateral views of cranidium. *26*, Cranidium. *28*, Pygidium (USNM 143064, plesiotypes).

boundary between the Conococheague and the underlying Elbrook limestone has not been clearly defined, it is possible that these beds should be assigned to the Elbrook. The latter formation is very poorly exposed at the locality. Most of the species discussed herein were collected from these strata in place, but some were found in greater numbers in loose blocks near the outcrop (loc. cce).

The faunule at locality ccf includes the species:

*Blountia virginica* Rasetti, n. sp.
*Coosina ariston* (Walcott)
*Glaphyraspis parva* (Walcott)
*Kingstonia*, sp. undet.
*Komaspidella lata* Rasetti, n. sp.
*Llanoaspis convexifrons* Rasetti, n. sp.
*Meteoraspis mutica* Rasetti, n. sp.
*Pemphigaspis*, sp. undet.
*Terranovella dorsalis* (Hall)

In addition, the following species were collected from loose blocks (locality cce):

*Komaspidella laevis* Rasetti, n. sp.
*Maryvillia arion* Walcott

Of these genera, *Coosina*, *Terranovella*, and *Komaspidella* are the most common. The faunule clearly belongs in the *Crepicephalus* zone (Lochman & Duncan, 1944), and several of the genera, such as *Coosina*, suggest the upper part of the *Crepicephalus* zone, which in central Texas was set off by Palmer (1954) under the name, *Maryvillia* zone. The author (Rasetti, 1956) has shown that this name should be changed to *Coosina* zone, as the designation was based on an incorrect interpretation of the genus *Maryvillia*. However, *Komaspidella* in the Upper Mississippi valley is more characteristic of the lower part of the *Crepicephalus* zone. Probably a better understanding of the age of the faunule will result from a pending investigation of the stratigraphic distribution of Dresbachian fossils in the Nolichucky formation of the southern Appalachians. In northeastern Tennessee (Rogersville area) a faunule with *Coosina ariston* and *Maryvillia arion* occurs approximately 450 feet above the base and 200 feet below the top of the Nolichucky formation.

*Limestones of the Frederick Valley.*—Bassler (1919) and Stose & Stose (1946) have discussed the stratigraphy of the Frederick valley of Maryland. It was early recognized that two types of limestone were present: a thin-bedded, dark-blue limestone with shaly partings, the so-called "building limestone," and a massive, light-gray, partly sandy or dolomitic limestone, the "quarry limestone." It was assumed that to each of these lithologic types corresponded a formation, and accordingly the thin-bedded limestone was named Frederick limestone, the other Grove limestone. While Bassler and previous authors believed that the massive limestone underlies the thin-bedded limestone, Stose & Stose, both on the basis of fossils and stratigraphic evidence gathered in exposures east of Frederick, reached the opposite conclusion that the Grove limestone overlies the Frederick. The Grove limestone yielded Canadian cephalopods and brachiopods from quarries southeast of Frederick and near LeGore, at the northeast boundary of the Paleozoic outcrop. The author (Rasetti, 1959) was able to show that the upper portion of the Frederick limestone in the eastern suburbs of Frederick and the lowermost Grove limestone in the same area both hold late Upper Cambrian (Trempealeauian) faunules, correlative with those of the *Hungaia magnifica* boulders at Levis, Quebec, a portion of the Gorge formation of northwestern Vermont and the Eminence dolomite of the Ozark uplift.

In view of all this evidence, there is hardly any doubt that the Grove limestone as defined from exposures in the Grove and LeGore quarries overlies the Frederick limestone and is partly of late Cambrian, partly of Canadian age.

However, from the present study one must conclude that the massive limestone in the western outcrops belts of the Frederick valley that was mapped as Grove by Stose & Stose, does not belong to that formation as it occupies a quite different stratigraphic position, underlying instead of overlying the Frederick limestone.

Evidence for this new interpretation is both of stratigraphic and paleontologic nature. Two main belts of supposed Grove limestone passing west of the city of Frederick appear on the map by Stose & Stose, surrounded by outcrop of Frederick limestone. Examination of the westernmost belt in pastures between Yellow Springs Road

(relocated in 1958) and the abandoned right-of-way of the Potomac Edison R.R. ($x = 212$ to 230, $y = 333$, Frederick Quadrangle, scale 1:24,000) shows a fairly thick, though not continuous, section of the so-called Grove limestone. It is clear that these beds form the axis of a broad anticline instead of a syncline as interpreted by Stose & Stose, thus representing older strata than the Frederick limestone which is exposed on both limbs of the anticline. Two excellent, though limited, exposures in quarries show thin-bedded limestone of the Frederick type overlying massive limestone of the "Grove" type. One is located on a low hill west of the south branch of Tuscarora Creek and of Willow Brook Road ($x = 303$, $y = 441$, Frederick quadrangle). According to the map, this exposure lies in the same belt as the above-mentioned anticline. Here the strata dip eastward about 30°. The other quarry is located in the other "Grove" outcrop belt of the map ($x = 327$, $y = 496$, Frederick quadrangle). Here the strata are almost horizontal and the relation of the two limestones is excellently shown. At both localities, unfortunately, only a very limited thickness of strata is exposed, especially of the overlying thin-bedded limestone. The contact is somewhat gradational, lenses of thin-bedded limestone appearing in the upper portion of the massive limestone.

In another fairly deep quarry, located in the northwest corner of the crossing of Opossumtown Pike and Willow Brook Road ($x = 306$, $y = 431$, Frederick quadrangle) a portion of the massive limestone is exposed, and interstratified thin beds yielded significant fossils. The strata dip about 30° east. The section described below was measured on the north and east faces of the quarry. In descending order the succession is:

Limestone: massive, sandy, light-gray, clearly showing bedding planes marked by more sandy layers. Sixteen feet exposed in quarry, higher beds partly exposed in pasture east of quarry to vicinity of Willow Brook Road 70+ feet

Limestone: massive limestone flat-pebble conglomerate, grading laterally to thin-bedded, fine grained, dark gray limestone. Interval weathers more readily than overlying and underlying strata. Fossils collected about 1 ft. above base in north and southeast parts of quarry (loc. ccm/4) 6 ft

Limestone: very massive, barely showing bedding planes, in part conglomeratic with sandy matrix enclosing angular, irregularly oriented pebbles of dark-gray, fine-grained limestone. Base of unit not exposed 35+feet

More numerous and better-preserved fossils were collected from loose blocks on a stone fence on the west side of Opossumtown Pike, 0.2 miles south of the above-mentioned quarry ($x = 305$, $y = 420$, Frederick quadrangle). Small exposures of both the massive conglomeratic limestone and the thin-bedded Frederick limestone occur in the immediate vicinity. The fossiliferous blocks are of dark-gray, slightly granular, medium-bedded limestone, resembling some of the strata of the Frederick limestone; they may be derived either from it, or from some thin-bedded interval in the upper portion of the massive limestone such as the one described in the above section. Only half a dozen fossiliferous blocks were found, all containing the same fauna. The locality is designated as ccm/3.

All together, several hundred more or less identifiable trilobite fragments were recovered from these limestones. The fossils in the quarry bed are extremely fragmentary and distorted, while those from the loose blocks are far better preserved. For this reason, material from the latter occurrence was chosen to represent the types of new species. Only a few inarticulate brachiopods of scarce stratigraphic significance were found in addition to the trilobites.

The trilobites from locality ccm/3 (loose blocks) are the following:

*Acmarhachis acuta* (Kobayashi)
*Bathyholcus gaspensis* Rasetti, n. gen., n. sp.
*Dunderbergia simplex* Rasetti, n. sp.
*Dunderbergia* cf. *variagranula* Palmer
*Glyptometopsis tumida* Rasetti, n. gen., n. sp.
*Glyptometopsis? marginata* Rasetti, n. sp.
*Pseudagnostus communis* (Hall & Whitfield)
*Pterocephalops acrophthalma* Rasetti
*Quebecaspis marylandica* Rasetti, n. sp.
*Quebecaspis conifrons* Rasetti, n. sp.
*Taenicephalites macrops* Rasetti, n. gen., n. sp.
Undetermined cranidia and pygidia

The faunule from the quarry (loc. ccm/4) includes the species:

*Acmarhachis acuta* (Kobayashi)
*Homagnostus*, sp. undet.
*Pseudagnostus communis* (Hall & Whitfield)
*Pterocephalops acrophthalma* Rasetti
*Quebecaspis marylandica* Rasetti, n. sp.
*Quebecaspis conifrons* Rasetti, n. sp.

*Taenicephalites macrops* Rasetti, n. gen., n. sp.
Undetermined cranidia and pygidia

The faunules of the loose blocks and the quarry beds cannot be very different in age, as they include several common species; only one named species from the quarry beds, the *Homagnostus*, was not found in the loose blocks. These faunules are entirely unrelated to any previously known from eastern North America, with the exception of certain conglomerate boulders from Quebec to be discussed presently. However, several species identical with or similar to those here described occur in the "post-*Aphelaspis*" faunizone in Texas (Palmer, 1954), later named the *Dunderbergia* faunizone by Lochman & Wilson (1958), and also in the Dunderberg shale of Nevada and the Jubilee limestone of British Columbia (Kobayashi, 1938; Palmer, 1960). The correlation is based on the presence of *Dunderbergia* at the Frederick valley localities, together with several agnostids known from the above-mentioned western areas. The other forms of the faunule here described belong to new genera.

It thus appears likely that the upper portion of the massive limestone, and possibly the basal portion of the overlying thin bedded (Frederick) limestone belong to the *Dunderbergia* zone. Hence the massive limestone cannot be the Grove limestone ranging in age from Trempealeauian to Canadian. The poor exposures and complicated structure of the Frederick valley make it impossible at present to ascertain whether the massive limestone occurs only as a continuous unit below the Frederick limestone, or whether massive limestone is also present at several levels, possibly in lenticular form, in the lower portion of the thin-bedded limestone. Fossils from localities ccm/3 and ccm/4 are provisionally referred to the Frederick (?) limestone.

Several of the genera and species discussed from the Frederick valley localities also occur in a few unusual boulders in the Ordovician conglomerates of the lower St. Lawrence valley. The author (Rasetti, 1944) described a faunule from boulder No. 51 in the Levis conglomerate at Levis, Quebec, listing three species each belonging to a new genus (*Onchopeltis spectabilis*, *Pterocephalops acrophthalma*, *Quebecaspis breviceps*). This boulder was recognized as older than the usual ones at the locality carrying the *Hungaia magnifica* faunule, but a precise age determination was impossible at the time since all these forms were unknown elsewhere. Now one of them, *Pterocephalops acrophthalma*, was collected at locality ccm/3, while another, *Quebecaspis breviceps*, is there represented by the very similar species *Quebecaspis marylandica*, and the third, *Onchopeltis spectabilis*, is certainly a very close relative of *Dunderbergia*. Furthermore, among the material from the Levis boulder No. 51 in the author's collections, were three additional species described herein, of which one, *Glyptometopsis? marginata*, also occurs in the faunule from locality ccm/3, while another, *Dunderbergia variagranula*, is characteristic of the *Dunderbergia* zone in Texas and Nevada.

In the author's collections were also two cranidia of an unusual trilobite, collected from a pebble in Lower Ordovician conglomerate at Grosses Roches, Matane County, Quebec. Boulders in that area yielded a variety of Lower, Middle, and Upper Cambrian faunules (Rasetti, 1945, 1946). Since no other species was associated with the trilobite in question, its age remained undetermined and it was left undescribed. Now the identical form also was found at locality ccm/3 and is described herein as *Bathyholcus gaspensis*. One may conclude that this also is a form of the *Dunderbergia* zone and that fossiliferous strata of that age were represented in the formations from which the boulders of the lower St. Lawrence valley were derived. The species of the *Dunderbergia* zone found in the Quebec boulders are listed below:

*Barthyholcus gaspensis* Rasetti, n. gen., n. sp.
*Bathyholcus sulcatus* Rasetti, n. sp.
*Dunderbergia variagranula* Palmer
*Glyptometopsis? marginata* Rasetti, n. sp.
*Onchopeltis spectabilis* Rasetti
*Pterocephalops acrophthalma* Rasetti
*Quebecaspis breviceps* Rasetti
Undetermined cranidium No. 2

## SYSTEMATIC DESCRIPTIONS

Excepting the agnostids, all the trilobites discussed herein fall in the ptychoparioid group, whose taxonomy is unsatisfactory. Less confusion will result by arranging the genera in alphabetical order rather

than assigning them to families of questionable significance.

In the explanation of the illustrations it is usually stated whether the figured specimen shows the outer surface of the test or the impression of the inner surface. Lack of this indication signifies that the preservation is so poor that the distinction cannot be made with certainty.

AGNOSTIDA

Genus ACMARHACHIS Resser, 1938

Type species: *Acmarhachis typicalis* Resser

ACMARHACHIS ACUTA (Kobayashi)
Pl. 23, figs. 1–8

*Homagnostus acutus* KOBAYASHI, 1938, p. 172, pl. 16, figs. 18–22.
*Pseudagnostus? acutus* (Kobayashi) PALMER, 1960, p. 62, pl. 4, figs. 10–12.

This species is by far the most common fossil at locality ccm/3. Both cephalon and pygidium agree well with the types from British Columbia, and with better preserved material from Nevada attributed to the species by Palmer.

*Occurrence.*—Loose blocks of Frederick (?) limestone, locality ccm/3. Also in place at locality ccm/4.

*Types.*—Plesiotypes: USNM 143051–2.

Genus HOMAGNOSTUS Howell, 1935

Type species: *Agnostus pisiformis obesus* Belt

HOMAGNOSTUS, sp. undet.
Pl. 23, figs. 9–12

Known from several cephala and pygidia in fair state of preservation. Both shields closely agree with the type species. Glabella somewhat tapered forward, with anterior lobe narrower than posterior lobe. Transverse glabellar furrow straight, shallow; median preglabellar furrow deep posteriorly but fading out before reaching the border furrow. Border furrow well marked, border narrow. Pygidial rachis very convex, prominent, narrowest between the two transverse furrows, slightly expanded in the well-rounded posterior lobe, separated from the border furrow by a distance slightly less than the border width. First pair of transverse rachial furrows impressed only laterally, directed slightly outward and backward; second furrow straight, interrupted medially by the usual elongated tubercle. Border wider than in cephalon.

Dr. Palmer (personal communication) informs the writer that species of *Homagnostus* of this type, characterized by the median furrow partly developed, occur in the western sections in strata of the approximate position of the *Dunderbergia* zone.

*Occurrence.*—Frederick (?) limestone in place at locality ccm/4.

*Disposition of material.*—Figured specimens: USNM 143053.

Genus PSEUDAGNOSTUS Jaekel, 1909

Type species: *Agnostus cyclopyge* Tullberg.

PSEUDAGNOSTUS COMMUNIS
(Hall & Whitfield)
Pl. 23, figs. 13–17

*Agnostus communis* HALL & WHITFIELD, 1877, p. 228, pl. 1, figs. 28, 29.
*Agnostus neon* HALL & WHITFIELD, 1877, p. 229, pl. 1, figs. 26, 27.
*Pseudagnostus communis* (Hall & Whitfield) PALMER, 1955, p. 94, pl. 19, figs. 16, 19–21; pl. 20, figs. 4–11, 14.

A form represented by numerous, mostly exfoliated cephala and pygidia does not differ significantly from topotype material of the species.

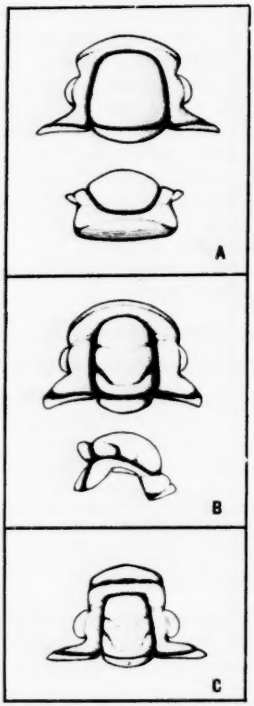
*Occurrence.*—Loose blocks from Frederick (?) limestone, locality ccm/3. Also in place at locality ccm/4.

*Types.*—Plesiotypes: USNM 143054–5.

Miscellaneous trilobites

Genus BATHYHOLCUS Rasetti, n. gen.

*Description.*—Cranidium strongly convex, with separate parts not greatly prominent. Glabella slightly tapered, defined by unusually deep and narrow dorsal furrow, not rising much above general convexity, unfurrowed. Occipital furrow deep and straight, occipital ring short (sag.) and simple. Frontal area downsloping, divided by border furrow at least laterally; preglabellar field short. Ocular ridges faint; palpebral area $\frac{1}{3}$ of glabellar width; palpebral lobes $\frac{2}{3}$ or more of glabellar length, situated halfway between anterior and posterior margins; palpebral furrow distinct. Anterior section of facial suture slightly divergent, anterior angles of cranidium rounded. Posterior section fairly straight to




TEXT-FIG. 1—A, *Bathyholcus gaspensis* Rasetti, n. gen., n. sp. Dorsal and frontal views of cranidium, ×2. B, *Glyptometopsis tumida* Rasetti, n. gen., n. sp. Dorsal and lateral views of cranidium, ×3. C, *Taenicephalites macrops* Rasetti, n. gen., n. sp. Cranidium, ×1.5.

posterior margin; posterior area almost as wide (tr.) as occipital ring, tapering to fairly sharp end, well furrowed.

*Type species.*—*Bathyholcus gaspensis*, Rasetti, n. sp.

*Occurrence.*—Upper Cambrian (*Dunderbergia* zone) of the Appalachians.

*Remarks.*—This genus of obscure affinities is distinguished from any other Cambrian trilobite known to the author by the depth and narrowness of the dorsal furrow.

BATHYHOLCUS GASPENSIS Rasetti, n. sp.
Pl. 23, figs. 18–23

*Available material.*—Two cranidia from the type locality, well preserved in limestone. Also a few distorted paratype cranidia from the Frederick (?) limestone.

*Description.*—Most of the characters are contained in the generic diagnosis. Glabella slightly tapered, somewhat truncated in front, anterior angles well rounded. Border furrow almost obsolete medially, distinct at sides; border convex, twice as wide (sag.) medially than the preglabellar field, tapering in width at sides, covered with low terrace lines. Palpebral lobes considerably curved. External surface covered with excessively fine granules. Length of largest cranidium 8 mm.

*Occurrence.*—The type locality is pebble G-11, in Ordovician conglomerate at Grosses Roches, Matane County, western Gaspé peninsula, Quebec. Paratypes were also collected from loose blocks of Frederick (?) limestone at locality ccm/3. No other species occurred in the pebble that yielded the type.

*Types.*—Holotype: USNM 143056. Paratypes: USNM 143057–8.

BATHYHOLCUS SULCATUS Rasetti, n. sp.
Pl. 23, figs. 24–26

*Available material.*—One cranidium well preserved in limestone.

*Description.*—Cranidium less convex than in preceding species. Glabella of same shape, also defined by a deep, narrow dorsal furrow, showing an extremely faint pair of lateral furrows. Anterior border furrow impressed throughout, deeper at sides; proportions of preglabellar field and border as in *B. gaspensis*. Palpebral area somewhat wider than in type species; palpebral lobes proportionately larger, attaining almost half of glabellar length. Posterior area not completely preserved, seemingly as in type species. Surface finely granulate. Length of cranidium 3.2 mm.

*Occurrence.*—Boulder 51 in Levis conglomerate on Middle Ridge at Levis, Quebec.

*Types.*—Holotype: USNM 143059.

Genus BLOUNTIA Walcott, 1916.

Type species: *Blountia mimula* Walcott.

BLOUNTIA VIRGINICA Rasetti, n. sp.
Pl. 21, figs. 1–5,8

*Available material.*—Numerous cranidia and pygidia well preserved in limestone.

*Description.*—Glabella with undifferentiated occipital ring strongly convex in both directions, tapered, well rounded in front,

four-fifths as wide as long. Dorsal furrow well impressed all around the glabella. Preglabellar field short (sag.), downsloping; border convex, somewhat wider (sag.) on midline than preglabellar field, also on average downsloping. Palpebral area downsloping, about one-fourth the width of the glabella at the same level. Palpebral lobes small, situated well in advance of glabellar midpoint. Posterior area relatively broad, less wide (tr.) than the occipital ring, with rather shallow border furrow. Anterior facial sutures slightly divergent, posterior section curving gently backward. Free cheek attributed to the species with wide border defined by a very shallow border furrow, seemingly not extended backward beyond the fixed cheek, the facial suture reaching the posterior margin at the genal angle which is narrowly rounded.

Pygidium of usual *Blountia* type, of little overall convexity. Axis tapered, not greatly elevated, almost unfurrowed on outer surface, but showing 8 distinct rings on interior casts, reaching four-fifths of the pygidial length. Pleural lobes rather flat, with traces of furrows on outer surface. Border faintly differentiated, of almost even width. Length of pygidium three-fourths of width. Surface of both shields smooth. Length of largest cranidium 7 mm., of largest pygidium 8 mm.

*Remarks.*—Notwithstanding the numerous species of *Blountia* that have been described, careful comparison with all the types in the U. S. National Museum did not produce any form with which the present one could be identified. The characters that distinguish *B. virginica* from most of the described species are the shape of the glabella, wider in proportion to the length and more tapered in the anterior portion than in almost all known species, the short frontal area, the relative proportions of preglabellar field and border, the downsloping attitude of the border, and the relatively blunt posterior area. The species that has a glabella most similar to the present one is *B. assimilis* Resser, but in that species the glabella is smaller compared to the other cranidial parts, the anterior border more elevated, and the posterior area wider (tr.).

*Occurrence.*—Dresbachian beds of Conococheague formation (localities cce, ccf) near Winchester, Virginia.

*Types.*—Holotype: USNM 143060. Paratypes: USNM 143061.

Genus CHEILOCEPHALUS Berkey, 1898

Type species: *Cheilocephalus stcroixensis* Berkey

CHEILOCEPHALUS, sp. undet.
Pl. 22, fig. 18

Several small, fragmentary cranidia of *Cheilocephalus* were collected from the Franconian beds of the Conococheague. This form seemingly has a proportionately wider and shorter glabella than described species, but the shape may be affected by distortion. The specimens may belong to *C. buttsi* Resser from beds of equivalent age in the Ore Hill limestone of central Pennsylvania.

*Occurrence.*—Locality ccc, near Winchester, Virginia.

*Disposition of material.*—Figured specimen: USNM 143062.

Genus COOSINA Rasetti, 1956.

Type species: *Maryvillia ariston* Walcott (part).

COOSINA ARISTON (Walcott)
Pl. 21, figs. 12,13

*Maryvillia ariston* WALCOTT (part), 1916, p. 401, pl. 64, figs. 5, 5′ (not fig. 5a).
*Coosina ariston* (Walcott). RASETTI, 1956, p. 1267. (Includes complete synonymy).

This is probably the most common fossil in the Dresbachian beds of the Conococheague at the Winchester locality. A pygidium and a cranidium of this widespread species are figured.

*Occurrence.*—Dresbachian beds of Conococheague formation (localities cce, ccf) near Winchester, Virginia.

*Types.*—Plesiotypes: USNM 143063.

Genus DRABIA Wilson, 1951

Type species: *Drabia acroccipita* Wilson

DRABIA CURTOCCIPITA Wilson
Pl. 22, figs. 25–28

*Drabia curtoccipita* WILSON, 1951, p. 640, pl. 94, figs. 22–25,27.
*Drabia* sp. undet. WILSON, 1951, p. 641, pl. 94, figs. 1,2.

Wilson commented on the distorted condition of his specimens of *Drabia curtoccipita* and figured a specimen with a wider glabella

and straighter anterior border as *Drabia* sp. undet. The author's collections at the type locality indicate that there is only one species of *Drabia* in those beds, and that the relatively narrow type cranidia of Wilson have undergone lateral compression. His unnamed cranidium represents the undistorted proportions. Hence the two forms are united under one name, and new, undistorted cranidia are figured. An associated pygidium, identical with the one figured by Wilson but better preserved, is also illustrated.

*Occurrence.*—Franconian beds of Conococheague formation (*Pseudosaratogia magna* faunule) in the suburbs of Winchester, Virginia. Wilson's type locality 45-1W-3. Specimens figured herein from author's localities ccc (loose blocks) and ccd (in place).

*Types.*—Plesiotypes: USNM 143064.

Genus DUNDERBERGIA Walcott, 1924

Type species: *Crepicephalus (Loganellus) nitidus* Hall & Whitfield.

DUNDERBERGIA VARIAGRANULA Palmer
Pl. 24, figs. 10–12

*Dunderbergia variagranula* PALMER, 1954, p. 761, pl. 88, figs. 7,9,10; pl. 89, fig. 1.

One small but well-preserved cranidium from Levis agrees with the types from Texas and additional material from Nevada collected by Palmer.

*Occurrence.*—Boulder No. 51 in Levis conglomerate, Levis, Quebec.

*Types.*—Plesiotype: USNM 143065.

DUNDERBERGIA sp. cf. D. VARIAGRANULA Palmer
Pl. 24, figs. 7–9

Several cranidia and a free cheek recovered from the Frederick (?) limestone may also represent this species or a very similar one. Only the figured cranidium, a large specimen, is well preserved. It seems to differ from typical material in the greater glabellar convexity, deeper glabellar furrows, and slightly shorter preglabellar field.

*Occurrence.*—Loose blocks of Frederick (?) limestone, locality ccm/3.

*Disposition of material.*—Figured specimens: USNM 143066.

DUNDERBERGIA SIMPLEX Rasetti, n. sp.
Plate 24, figs. 1–6

*Available material.*—Several well preserved cranidia and a few free cheeks.

*Description.*—Cranidium of moderate convexity. Glabella not greatly elevated, of usual shape, with two pairs of faint furrows. Occipital ring short (sag.), bearing a small node. Preglabellar field somewhat longer (sag.) than the width (sag.) of the convex border. Border furrow rather straight, with but a suggestion of the angular shape observed in other forms of the genus. Palpebral area convex and slightly upsloping; palpebral lobes wide, upsloping. Anterior sections of facial sutures slightly divergent, anterior angles of cranidium narrowly rounded; posterior section fairly straight, defining long (tr.), tapering posterior area. Free cheek with definite border furrow and border, extended into a flat, genal spine; visual surface of eye a very narrow band. Surface of test showing fine, indistinct granules. Length of largest cranidium 12 mm.

*Remarks.*—The species differs from *D. nitida* in the proportionately longer glabella, shorter preglabellar field, and wider border; also in the larger size of the palpebral lobes. The shorter preglabellar field, straight border furrow, lesser convexity, and almost smooth surface also distinguish it from *D. variagranula*.

*Occurrence.*—Loose blocks of Frederick (?) limestone, locality ccm/3.

*Types.*—Holotype: USNM 143067. Paratypes: USNM 143068.

Genus GLAPHYRASPIS Resser, 1937

Type species: *Liostracus parvus* Walcott.

The type material of *Liostracus parvus* Walcott never having been properly illustrated, the characters of *Glaphyraspis* were not clearly understood. Examination of the types revealed that this species is certainly congeneric with *Raaschella ornata* Lochman. Hence the name *Raaschella* Lochman, 1938, is a junior subjective synonym of *Glaphyraspis* Resser, 1937.

GLAPHYRASPIS PARVA (Walcott)
Pl. 22, figs. 14–17

*Liostracus parvus* WALCOTT, 1899, p. 463, pl. 65, fig. 6.

*Glaphyraspis parva* (Walcott). RESSER, 1937, p. 12.

Several cranidia do not appear specifically distinct from the type material from Yellowstone National Park.

This species differs from *G. ornata* (Lochman) in the proportionately narrower and longer glabella, shallower dorsal furrow, shallower third and fourth pairs of glabellar furrows, presence of a more distinct second pair, proportionately narrower anterior portion of the cranidium, and smaller size of all the known specimens.

*Occurrence.*—Dresbachian beds of the Conococheague formation (loc. ccf) near Winchester, Virginia.

*Types.*—Plesiotypes: USNM 143069.

GLAPHYRASPIS OVATA Rasetti, n. sp.
Pl. 22, figs. 19–24

*Available material.*—Numerous cranidia well preserved in limestone.

*Description.*—Glabella very convex, subovate, slightly tapered forward, rounded in front. Posterior lateral furrows of moderate depth, curving backward, becoming very shallow toward the occipital ring; another pair short and shallow. Occipital furrow deep, occipital ring short, not bearing spine or node. Preglabellar field almost vanishing medially; border furrow shallow; border convex, tapering in width at the sides. Palpebral area convex, on average downsloping; ocular ridges indistinct; palpebral lobes short and narrow, considerably anterior to level of glabellar midpoint. Anterior facial sutures convergent; posterior section directed first outward and then backward, defining stout posterior area. Posterior area curving downward, deeply furrowed. Surface of test finely granulate. Length of largest cranidium 3.2 mm.

*Remarks.*—The basic structure of the cranidial parts is the same as in the type species, but the proportions are somewhat different in the more convex, rounded glabella, reduction of the preglabellar field, and shortness of the occipital ring. These characters distinguish it also from *G. ornata* Lochman. The previously described species of the genus are older, occurring in the *Crepicephalus* and *Aphelaspis* zones.

*Occurrence.*—Franconian beds of the Conococheague formation (locality ccd) near Winchester, Va.

*Types.*—Holotype: USNM 143070. Paratypes: USNM 143071.

Genus GLYPTOMETOPSIS Rasetti, n. gen.

*Description.*—Glabella very convex, almost parallel-sided, rounded in front, with at least one well-marked pair of lateral furrows; occipital ring not spinose. Fixed cheeks downsloping; frontal area divided by shallow border furrow; border not elevated, moderately arched transversely; palpebral area about ⅓ the glabellar width; palpebral lobes of medium size, at level of glabellar midpoint; ocular ridges present. Anterior facial sutures not greatly divergent, posterior section directed at 45°, posterior area rounded.

*Type species.*—*Glyptometopsis tumida* Rasetti, n. sp.

*Remarks.*—This is one of the numerous ptychoparioid trilobites of the convex, short-brimmed type, but, notwithstanding the resemblance to a number of described forms, has a combination of features not fitting any described genus. A possible affinity is with the trilobites that were assigned by the author to the family Lonchocephalidae in the *Treatise on Invertebrate Paleontology*, such as *Welleraspis*, *Glaphyraspis*, and *Glyptometopus*. The convex preglabellar field and lack of elevation of the border distinguish the present form from most otherwise similar genera.

GLYPTOMETOPSIS TUMIDA Rasetti, n. sp.
Pl. 23, figs. 27–34

*Available material.*—Numerous cranidia in limestone, exfoliated and somewhat distorted.

*Description.*—Glabella very convex, slightly tapered, well rounded in front; posterior lateral furrows deep, curving backward, in some specimens appearing connected through a shallow median portion; another pair short and shallow. Occipital furrow wide and deep, occipital ring simple. Preglabellar field longitudinally convex, about twice as wide (sag.) as the border; border furrow shallow; border narrow (sag.) of about even width, not elevated. Palpebral area slightly convex, ⅓ the glabellar width; ocular ridges narrow, oblique, well marked

on internal surface; palpebral lobes defined by palpebral furrow, moderately wide, slightly less than $\frac{1}{3}$ the glabellar length. Anterior sections of facial sutures appearing almost parallel in dorsal view, slightly convex outward; anterior angles of cranidium rounded. Posterior section directed outward and backward without much curvature; posterior area deeply furrowed, rounded off distally, narrower (tr.) than occipital ring. Surface of test not preserved, seemingly without coarse ornamentation. Length of largest cranidium 7 mm.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Types.*—Holotype: USNM 143072. Paratypes: USNM 143073.

GLYPTOMETOPSIS? MARGINATA
Rasetti, n. sp.
Pl. 25, figs. 12–15

*Available material.*—The holotype and two other cranidia from the type locality, plus one cranidium from the Frederick (?) limestone.

*Description.*—Glabella prominent, very convex anteriorly, with straight, slightly convergent sides and well-rounded front, almost reaching border furrow; posterior lateral furrows deep, directed backward, connected by a shallow, straight portion; another pair short and shallow. Occipital ring short (sag.), bearing a small node. Preglabellar field almost vanishing medially; border somewhat convex, of moderate width. Palpebral area slightly convex and upsloping, about $\frac{1}{4}$ the glabellar width; ocular ridges faint; palpebral lobes almost $\frac{1}{3}$ the glabellar length, well defined by palpebral furrow. Anterior sections of facial sutures moderately divergent, anterior angles of cranidium fairly sharp. Posterior section first directed outward and then backward; furrowed posterior area narrower (tr.) than occipital ring. Surface finely granulate. Length of largest cranidium 3.4 mm.

*Remarks.*—The generic assignment is questioned on account of the considerable difference between this form and the type species in the structure of the frontal area. However, no reference to any described genus seems more plausible.

*Occurrence.*—The type is from boulder 51 in Levis conglomerate, on Middle Ridge, Levis, Quebec. One paratype was collected from loose blocks of Frederick (?) limestone at locality ccm/3.

*Types.*—Holotype: USNM 143074. Paratypes: USNM 143075–6.

Genus KOMASPIDELLA Kobayashi, 1938

Type species: *Agraulos thea* Walcott

KOMASPIDELLA LATA Rasetti, n. sp.
Pl. 21, figs. 18–24

*Available material.*—Numerous cranidia and pygidia, well preserved in limestone but showing slight distortion.

*Description.*—Glabella subquadrate, moderately rounded in front, about equally long and wide, fairly convex in both directions, set off by a deep dorsal furrow. Posterior pair of glabellar furrows of usual pattern barely indicated on the outer surface. Occipital furrow straight, well impressed throughout, occipital ring short (sag.). Frontal area reduced to a narrow (sag.), convex, undifferentiated band. Palpebral area approximately horizontal, slightly convex, $\frac{1}{4}$ as wide as the glabella; palpebral lobes slightly elevated, $\frac{1}{4}$ as long as the glabella, set off by a shallow palpebral furrow. Anterior facial sutures slightly convergent in front of the eyes, curving gently inward and producing a well-rounded anterior cranidial outline. Posterior section directed straight outward, producing a slender, parallel-sided posterior area; curving backward and reaching the posterior margin close to genal angle. Posterior area with deep border furrow.

Pygidium slightly wider than long, subtriangular. Axis elevated, subcylindrical, almost reaching the posterior margin, with 8 or 9 progressively less distinct rings and a terminal section. Pleural lobes convex, with a faint indication of a border furrow; border down-rolled. Anterior border furrow well impressed, other pleural furrows barely indicated on outer surface.

Surface of test smooth. Length of largest cranidium and largest pygidium 6 mm.

*Remarks.*—This form is similar to both of the two previously described species, *K. thea* from the upper Mississippi valley (illustrated by Raasch & Lochman, 1943), and *K. seelyi* (Walcott) from the Potsdam sandstone. Close comparison is made diffi-

cult by the fact that all the material of *K. seelyi* and *K. thea* consists of sandstone casts, while the present species is represented by limestone material preserving the test. A difference from both described species is the proportionately shorter and wider glabella; there is some variation in this respect, presumably due to distortion, but on the average the difference in proportions from the two above-mentioned species is definite. Another difference from *K. seelyi* is the better-defined pygidial border in the latter species, even when allowance is made for the different preservation. The pygidium differs from that of *K. thea* in being proportionately longer and narrower and having a much less tapered axis.

It is surprising that this genus which is common in the lower Conococheague had never been reported from the central or southern Appalachians.

*Occurrence.*—Common at localities cce, ccf (type from the former); Dresbachian beds of Conococheague formation near Winchester, Virginia.

*Types.*—Holotype: USNM 143077. Paratypes: 143078.

KOMASPIDELLA LAEVIS Rasetti, n. sp.
Pl. 21, figs. 6,7,9–11

*Available material.*—Numerous cranidia and pygidia excellently preserved in limestone.

*Description.*—Glabella parallel-sided, four-fifths as wide as long, convex in both directions, well defined all around by a narrow dorsal furrow. Occipital furrow moderately deep, occipital ring short (sag.) and simple. Frontal area reduced to a very narrow (sag.) strip. Palpebral area downsloping, not rising above the level of the dorsal furrow. Palpebral lobes, posterior area, and facial sutures as in preceding species. The border furrow on the posterior area is well impressed but becomes obsolete before reaching the margin.

Pygidium of same proportions as in preceding species, differing in the more strongly downturned border, so that there is no trace of border furrow, axis slightly expanded at both ends, and more numerous axial segments. About 12–14 rings are present, barely indicated on the outer surface.

Surface of test smooth. Length of largest cranidium 4.6 mm., of largest pygidium 5.6 mm.

*Remarks.*—This form differs from *K. thea* and *K. seelyi* in the downsloping palpebral area, narrower frontal area, and nontapered pygidial axis composed of more numerous segments. Most of these characters separate it also from *K. lata*.

*Occurrence.*—Dresbachian beds of Conococheague formation (loc. cce) near Winchester, Virginia.

*Types.*—Holotype: USNM 143079. Paratypes: USNM 143080.

Genus LLANOASPIS Lochman, 1938

Type species: *Llanoaspis modesta* Lochman.

LLANOASPIS CONVEXIFRONS Rasetti, n. sp.
Pl. 22, figs. 1–6

*Available material.*—Several cranidia, free cheeks and pygidia preserved in limestone but somewhat distorted.

*Description.*—Glabella very convex in both directions, slightly tapered, well raised above the dorsal furrow; posterior glabellar furrows shallow, two other pairs indistinct. Occipital furrow well impressed throughout, occipital ring rounded. Palpebral area steeply upsloping, bringing the palpebral lobes to an elevated position. Border flat; border furrow present laterally but very shallow. Posterior area long (tr.), very narrow (exsag.) proximally, expanding distally to 2½ times its proximal (exsag.) width, rounded at the extremity. Posterior border furrow deep, turning forward on the distal portion of the posterior area. This shape of the posterior area, common to most species of *Llanoaspis*, is reflected in the peculiar course of the posterior section of the facial suture visible on the free cheek. The free cheek also has a broad, rather flat border and a very shallow border furrow; the border is extended into a broad, long, flat genal spine whose outer margin continues the regular curvature of the sides of the cephalon. Surface of cranidium smooth.

Pygidium subtriangular, twice wider than long. Axis slightly tapered, showing 7 or 8 rings separated by increasingly shallow furrows, occupying the entire pygidial length. Pleural platforms moderately convex, not steeply downsloping even in the distal portion, terminating into a broad border fur-

row; border narrow and poorly defined. Five or 6 pairs of pleural furrows visible, the last pair indistinct; interpleural grooves shallow, better impressed on the downsloping portion of the pleural platform; furrows and grooves curving rather sharply backward on this slope and becoming obsolete in the border furrow. Each rib between the pleural furrow and the following groove has a few tubercles, otherwise the surface is smooth.

Length of largest cranidium 5.5 mm., of largest pygidium 3.6 mm.

*Remarks.*—This species differs from the described forms of the genus in one or more of the following characters: highly convex glabella, rather indistinct anterior border furrow, and lack of lateral expansion of the pygidial border. The closest described species is *Llanoaspis peculiaris* Resser from the southern Appalachians. However, in the type cranidium of that species the posterior area does not appear to expand distally as in the present species, and the pygidium has a lesser number of pleural furrows. Palmer (1954) assigned to *L. peculiaris* specimens from Texas with posterior area expanding distally, although not as strongly as in the material figured herein.

*Occurrence.*—Dresbachian beds of the Conococheague formation (loc. cce, ccf) near Winchester, Virginia.

*Types.*—Holotype: USNM 143081. Paratypes: USNM 143082.

Genus MARYVILLIA Walcott, 1916

Type species: *Maryvillia arion* Walcott

MARYVILLIA ARION Walcott
Pl. 21, figs. 14,15

*Maryvilla arion* WALCOTT, 1916, p. 400, pl. 64, figs. 4-4c.
*Maryvilla arion* Walcott. RASETTI, 1956, p. 1267 (includes complete synonymy).

A few associated cranidia and pygidia do not present any specific differences from the types of the species.

*Occurrence.*—Dresbachian beds of the Conococheague formation (loc. cce, loose blocks) near Winchester, Virginia.

*Types.*—Plesiotypes: USNM 143083.

Genus METEORASPIS Resser, 1935

Type species: *Ptychoparia? metra* Walcott

METEORASPIS MUTICA Rasetti, n. sp.
Pl. 21, figs. 25–29

*Available material.*—About half a dozen cranidia and as many free cheeks and pygidia tentatively attributed to the same species.

*Description.*—The cranidium needs little description as it does not differ appreciably from those of several described species of *Meteoraspis*. Glabella of usual shape and convexity, defined by a deep dorsal furrow; glabellar furrows obsolete. Occipital furrow well impressed, occipital ring not well preserved. Fixed cheeks steeply downsloping; palpebral area less than one-fourth as wide as the glabella, palpebral lobe of usual shape and position. Preglabellar field shorter (sag.) than median width of border. Border convex, expanded medially, arched transversely. The border furrow has three shallow, broad depressions instead of two as in *M. metra* and most of the described species of the genus. The free cheeks have a broad border like those described in other species.

The pygidia found closely associated with the cranidia could not be attributed to any other trilobite present in the same strata and are tentatively assigned to the species, although they differ considerably from the typical pygidia of *Meteoraspis*. Pygidium less than twice wider than long, with rounded sides and a broad median notch in the posterior margin. Axis wide and short, well elevated above the pleural lobes, with two rings defined by clear furrows and a terminal section, occupying over two-thirds of the pygidial length. Pleural lobes on the average convex and downsloping. Immediately posterior to the first pleural furrow, a prominent broad rib curves backward and subsequently inward, its extension forming a somewhat indistinct elevated border. This rib is followed by a depression apparently resulting from a second pleural furrow plus an interpleural groove, then a second less prominent rib, also merging with the border. The posterior pygidial margin appears notched in dorsal view, elevated medially as an inverted V in posterior view. The surface of the test is finely granulated.

The largest cranidium has a length of 9 mm.; the largest pygidium is 5 mm. wide and 3 mm. long.

*Remarks.*—While the cranidium offers no marked differences from those of described species, the pygidium differs in the lack of a pair of spines. Of the known species, *Meteoraspis spinosa* Lochman has the pygidium with the shortest spines; if these were further reduced to rounded lobes, a pygidium similar to the present one would result. Hence the reference of the pygidium to *Meteoraspis* seems plausible. The same association of pygidium and cranidium occurs in the *Crepicephalus* zone of the Nolichucky formation near Rogersville, Tennessee. The holotype is a pygidium, hence the name will remain associated with this part in case cranidium and pygidium do not belong to one species.

*Occurrence.*—Dresbachian beds of the Conococheague formation (loc. ccf) near Winchester, Virginia.

*Types.*—Holotype: USNM 143084. Paratypes: USNM 143085.

Genus PEMPHIGASPIS Hall, 1863

Type species: *Pemphigaspis bullata* Hall.

PEMPHIGASPIS sp. undet.
Pl. 21, figs. 16,17

A few, incomplete cranidia and pygidia represent the genus. This form seemingly differs from *P. bullata* in the greater depth of the outer portion of the glabellar furrows, and especially in the lesser number of segments in the pygidial axis. It would be improper to name a new species on such incomplete material.

*Occurrence.*—Lower Conococheague formation; locality ccf, near Winchester, Virginia.

*Disposition of material.*—Figured specimens: USNM 143086.

Genus PTEROCEPHALOPS Rasetti, 1944

Type species: *Pterocephalops acrophthalma* Rasetti

PTEROCEPHALOPS ACROPHTHALMA
Rasetti
Pl. 24, figs. 13–16

*Pterocephalops acrophthalma* RASETTI, 1944, p. 254, pl. 39, figs. 35–38.

A few cranidia seem identical with the types. A feature not previously observed, present both in topotype material and the new specimens, is the presence of fairly large, scattered tubercles on the anterior border and on the posterior portion of the preglabellar field.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3. Also in place at locality ccm/4.

*Types.*—Plesiotypes: USNM 143087–8.

Genus QUEBECASPIS Rasetti, 1944

Type species: *Quebecaspis breviceps* Rasetti.

QUEBECASPIS MARYLANDICA
Rasetti, n. sp.

*Available material.*—Numerous cranidia and a few free cheeks, moderately well preserved in limestone.

*Description.*—Glabella of low convexity, moderately tapered, truncated in front, reaching the border furrow; two pairs of shallow glabellar furrows of the same character as in type species. Occipital ring extended into a broad, short spine. Border convex, relatively narrow, somewhat curved. Ocular ridges barely indicated; palpebral lobes narrow, somewhat less than half the glabellar length; palpebral area 0.25 of glabellar width. Posterior area half as wide (tr.) as base of glabella, deeply furrowed, bluntly terminated. Surface apparently smooth. Length of largest cranidium 6 mm. Free cheek relatively narrow, with broad border well defined anteriorly but fading posteriorly; furrow on posterior area of cranidium connects with rearward-directed furrow on free cheek separated from lateral border furrow; genal spine flat, curved, short, rapidly tapering.

*Remarks.*—This form is similar to the type species, differing mainly in the complete lack of a preglabellar field, less straight anterior border, proportionately longer and narrower glabella, and narrower palpebral lobes.

*Occurrence.*—Loose blocks of Frederick (?) limestone, locality ccm/3. Also common in place at locality ccm/4.

*Types.*—Holotype: USNM 143089. Paratypes: USNM 143090–1.

QUEBECASPIS CONIFRONS Rasetti, n. sp.
Pl. 24, figs. 23–25

*Available material.*—Three cranidia imperfectly preserved.

*Description.*—Glabella relatively short and wide, very rapidly tapered, reaching the border furrow. Glabellar furrows indistinct on outer surface, shallow but visible on interior cast, the posterior pair sharply curving backward and almost joining the occipital furrow. Occipital ring seemingly simple. Border convex, fairly straight. Ocular ridges distinct. Palpebral lobes not preserved, seemingly occupying same position as in type species. Posterior area as in *Q. marylandica*. Length of largest cranidium 3.2 mm.

*Remarks.*—This form is readily distinguished from the other two described species by the strongly tapered glabella.

*Occurrence.*—The holotype is from loose blocks of Frederick (?) limestone at locality ccm/3. One paratype was collected in place at locality ccm/4.

*Types.*—Holotype: USNM 143092. Paratypes: USNM 143093–4.

Genus TAENICEPHALITES Rasetti, n. gen.

*Description.*—Glabella tapered, straight-sided, truncated in front, defined by deep, wide dorsal furrow; glabellar furrows visible at least on inner surface, narrow; posterior pair sigmoidal. Occipital furrow deep, occipital ring short (sag.). Frontal area divided into convex preglabellar field and convex border; border furrow fairly straight, anterior border outline somewhat pointed medially; three shallow pits sometimes visible in border furrow. Palpebral area narrow, upsloping; ocular ridges distinct; palpebral lobes about half the glabellar length, elevated, defined by palpebral furrow. Anterior sections of facial sutures almost straight and parallel in dorsal view; posterior section directed almost straight outward, defining slender posterior area about as wide (tr.) as occipital ring, pointed distally, deeply furrowed. Free cheek with well-defined lateral and posterior border furrow, rather slender genal spine of medium length.

*Type species.*—*Taenicephalites macrops* Rasetti, n. sp.

*Occurrence.*—Upper Cambrian (*Dunderbergia* zone) of the central Appalachians.

*Remarks.*—This form resembles a number of Upper Cambrian ptychoparioid genera, especially from the *Elvinia* and *Conaspis* zones, but is sufficiently distinct to warrant separate recognition. The name was chosen to indicate the resemblance to *Taenicephalus*, from which it differs mainly in the larger and more posteriorly situated palpebral lobes and the corresponding slenderness of the posterior area. *Taenicephalites* may be related to *Aphelaspis* and similar late Dresbachian genera.

TAENICEPHALITES MACROPS
Rasetti, n. sp.
Pl. 25, figs. 1–11

*Available material.*—Numerous cranidia, preserved in limestone but mostly exfoliated and somewhat distorted; also a few free cheeks.

*Description.*—Glabella showing two pairs of furrows on internal surface, posterior pair in most specimens appearing connected by very shallow extension through glabellar midline. Occipital ring very short (sag.), bearing a small node. Dorsal furrow wide and deep laterally, shallower and narrower in front, with more or less distinct pits at anterior angles. Palpebral area convex and upsloping, about ⅓ as wide as glabella; palpebral lobes marked by wide palpebral furrow, rising above palpebral area, wide, somewhat over half the glabellar length, their midpoint somewhat posterior to glabellar midlength. Preglabellar field and border of equal width (sag.) on midline; border furrow fairly straight, showing three shallow, broad pits in some specimens; anterior border outline somewhat pointed medially, hence border tapering laterally. Anterior section of facial suture almost straight to border furrow; posterior section long, slightly curved. Surface not well preserved, apparently smooth. Ocular platform of free cheek with anastomosing lines. Length of largest cranidium 11 mm.

*Occurrence.*—Loose blocks of Frederick limestone at locality ccm/3. Also in place at locality ccm/4.

*Types.*—Holotype: USNM 143095. Paratypes: USNM 143096–7.

Genus TERRANOVELLA Lochman, 1938

Type species: *Terranovella obscura* Lochman

TERRANOVELLA DORSALIS (Hall)
Pl. 22, figs. 7–13

*Conocephalites? (Arionellus?) dorsalis* HALL, 1863, p. 222.
*Ptychoparia dorsalis* (Hall). VOGDES, 1890, p. 141.
*Lonchocephalus sospita* WALCOTT, 1916, p. 195, pl. 36, figs. 1,1a.
*Terranovella buttsi* RESSER, 1938, p. 100, pl. 15, figs. 22–26.
*Terranovella dorsalis* (Hall). RAASCH & LOCHMAN, 1943, p. 234, pl. 35, figs. 3–10, 17.

There is hardly any doubt that the names *dorsalis* and *sospita*, both based on material from the Eau Claire sandstone of the Upper Mississippi valley, represent the same species. Comparison of the type material of *T. sospita* with *T. buttsi* from the southern Appalachians, notwithstanding the different manner of preservation, shows no difference of specific value. Possibly other names proposed by Resser are also synonymous. A very common form of the lower Conococheague seems to represent this species.

The only remark to be added to the detailed description given by Raasch & Lochman concerns the ornamentation. The cranidia are finely punctate, the density of the puncta being variable from one individual to another. The ocular platforms of the free cheeks are more densely and distinctly punctate. The border of the free cheeks is covered with irregular, interconnecting lines.

*Occurrence.*—Common in the Dresbachian beds of the Conococheague formation (loc. cce, ccf) near Winchester, Virginia.

*Types.*—Plesiotypes: USNM 143098.

## Undetermined Trilobites

Several forms of the *Dunderbergia* zone from the Frederick (?) limestone are figured and described on account of the stratigraphic importance of the faunule, even though they are not represented by sufficiently abundant or well-preserved material to be worth naming. Four cranidia in this category cannot be assigned to described genera. A number of associated pygidia were recovered. As there is a variety of cranidia, most of which are poorly known or unknown elsewhere, there is little ground on which to base tentative references of cranidia and pygidia to the same species. To avoid confusing mistakes, the pygidia are separately described without assignment.

Trilobite fragments from the *Dunderbergia* zone, especially the beds at locality ccm/4, indicate the presence of other species in addition to those described herein, too poorly represented to warrant illustration.

### Undetermined cranidium no. 1
Pl. 25, figs. 25–27

Represented by one poorly preserved example. Glabella almost parallel-sided, defined by a deep and wide dorsal furrow, rounded in front, very convex transversely, seemingly unfurrowed. Frontal area more than half as long (sag.) as glabella, consisting of tumid preglabellar field and narrow, slightly convex border. Border furrow parallel to anterior margin. Palpebral area convex and somewhat upsloping, not much narrower than glabella; ocular ridges indistinct; palpebral lobes not preserved, seemingly small and at level of glabellar midpoint. Anterior facial sutures flaring out considerably, anterior angles of cranidium rounded. Posterior area not preserved. Test not preserved; interior cast showing few, large scattered tubercles on preglabellar field and border. Length of cranidium 9.5 mm.

This is a ptychoparioid trilobite of fairly generalized structure with a combination of features not present in described Upper Cambrian genera.

*Occurrence.*—Quarry in Frederick (?) limestone at locality ccm/4.

*Disposition of material.*—Figured specimen: USNM 143099.

### Undetermined cranidium no. 2
Pl. 23, figs. 35,36

Represented by two individuals well preserved in limestone. Glabella slightly tapered, very prominent, rounded in front. Posterior lateral furrows shallow, directed backward, with a bare indication of a connection across the glabella; another pair short and exceedingly faint. Occipital ring short (sag.), with a small node.

Frontal area concave longitudinally, with a trace of a border furrow which seems to indicate that most of the length (sag.) at least medially belongs to the border. Anterior outline of cranidium regularly curved. Ocular ridges distinct; palpebral area about $\frac{1}{6}$ the glabellar width; palpebral lobes about $\frac{1}{4}$ the glabellar length, palpebral furrow well impressed. Anterior sections of facial sutures

divergent, anterior angles of cranidium narrowly rounded. Posterior section directed outward and backward, posterior area somewhat more than half as wide (tr.) as occipital ring. Surface of test finely granulate. Length of larger cranidium 4.4 mm.

This cranidium resembles a number of ptychoparioid Upper Cambrian genera, but does not have the proper combination of characters to be definitely assigned to a described genus. In some features it resembles *Bellaspis billingsi* which, however, has a well-defined, convex border.

*Occurrence.*—Boulder No. 51 in Levis conglomerate at Levis, Quebec.

*Disposition of material.*—Figured specimen: USNM 143100.

Undetermined cranidium no. 3
Pl. 24, fig. 26

Known from two specimens. Entire cranidium of low convexity. Glabella low, straight-sided, somewhat tapered, fairly truncated in front, with 2 pairs of shallow lateral furrows; occipital ring simple. Frontal area about $\frac{1}{2}$ the glabellar length; border furrow distinct; border convex, of uniform width, bearing a series of tubercles, much narrower (sag.) than the preglabellar field. Ocular ridges straight, oblique; palpebral area somewhat more than half as wide as glabella; palpebral lobes small, situated a little back of glabellar midlength. Anterior sections of facial sutures well divergent; posterior section first directed outward and then backward. Posterior area slender, well furrowed, about as wide (tr.) as occipital ring. Length 4 mm.

This form resembles several generalized Middle Cambrian ptychoparioids rather than Upper Cambrian genera.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimen: USNM 143101.

Undetermined cranidium no. 4
Pl. 24, fig. 27

Known from one fairly complete example and several fragments. Cranidium of low convexity. Glabella parallel-sided, not greatly elevated, rounded in front, unfurrowed; occipital furrow impressed, occipital ring simple. Frontal area convex, with a poorly defined, very narrow border. Ocular ridges faint; palpebral lobes small, at level

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EXPLANATION OF PLATE 23

All the figured specimens represent the fauna of the *Dunderbergia* zone.

FIGS. *1–8*—*Acmarhachis acuta* (Kobayashi), ×5. *1*, Cephalon with unusually narrow border. *2,3*, Typical cephala. *4–6*, Pygidia. Specimens preserving test, loc. ccm/3 (USNM 143051, plesiotypes). *7,8*, Cephalon and pygidium; loc. ccm/4 (USNM 143052, plesiotypes).

*9–12*—*Homagnostus* sp. undet., ×8. *9,10*, Cephala. *11,12*, pygidia. Loc. ccm/4 (USNM 143053).

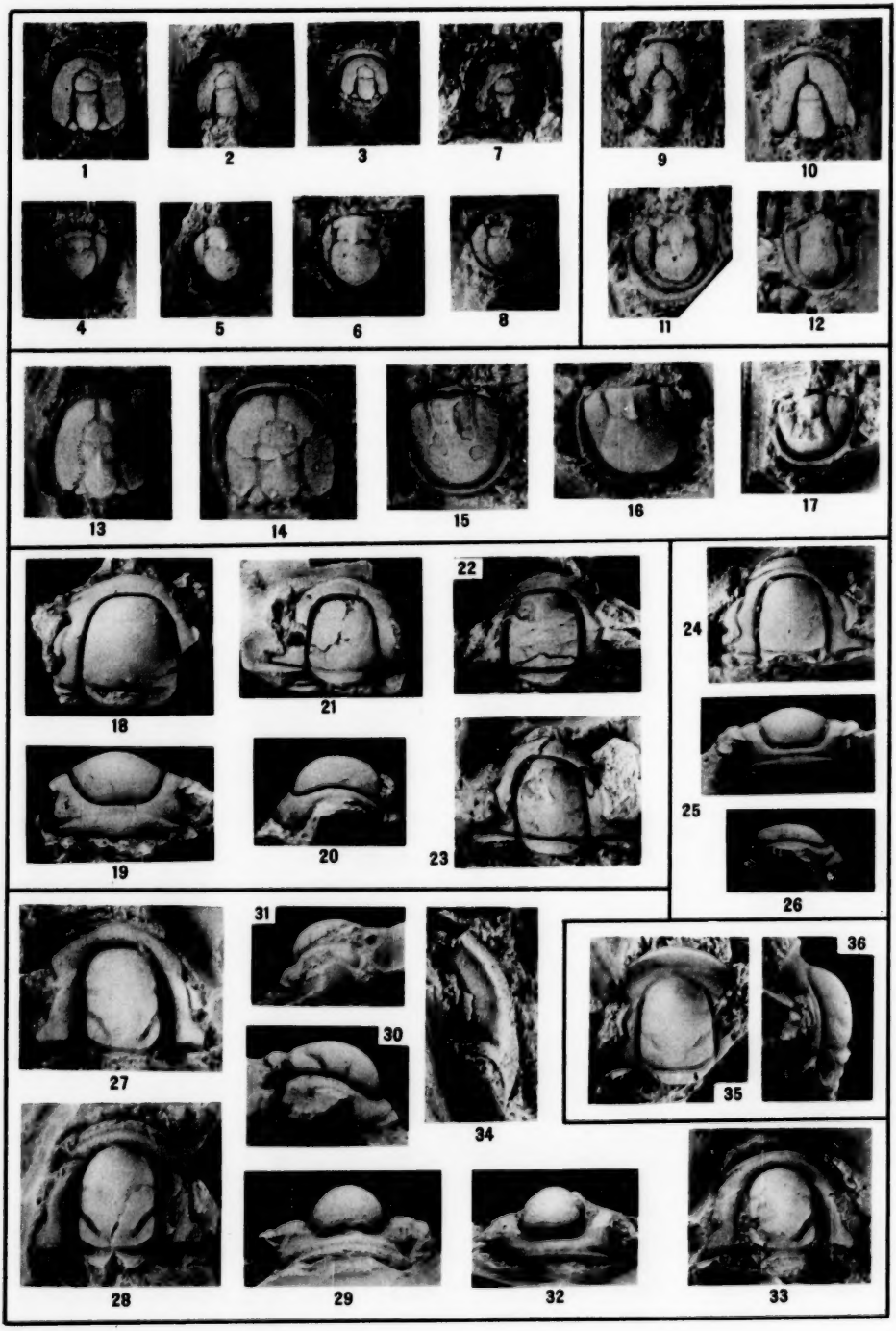
*13–17*—*Pseudagnostus communis* (Hall & Whitfield), ×5. *13,14*, Exfoliated cephala. *14*, Pygidium preserving test. *16*, Exfoliated pygidium. Loc. ccm/3 (USNM 143054, plesiotypes). *17*, Pygidium; loc. ccm/4 (USNM 143055, plesiotype).

*18–23*—*Bathyholcus gaspensis* Rasetti, n. gen., n. sp., ×3. *18–20*, Dorsal, frontal, and lateral views of cranidium preserving test (USNM 143056, holotype). *21*, Cranidium preserving test (USNM 143057, paratype). Boulder G-11 in conglomerate at Grosses Roches, Matane County, Quebec. *22*, Exfoliated cranidium. *23*, Cranidium preserving most of test. Loc. ccm/3 (USNM 143058, paratypes).

*24–26*—*Bathyholcus sulcatus* Rasetti, n. sp., ×5. Dorsal, frontal and lateral views of cranidium preserving test. Boulder 51 in Levis conglomerate at Levis, Quebec (USNM 143059, holotype).

*27–34*—*Glyptometopsis tumida* Rasetti, n. gen., n. sp. (all specimens exfoliated). *28–30*, Dorsal, frontal and lateral views of cranidium, ×4 (USNM 143072, holotype). *27*, Cranidium, ×4. *31–33*, Lateral, frontal and dorsal views of cranidium, ×3. *34*, Free cheek presumably belonging to the species, ×5 (USNM 143073, paratypes). Loc. ccm/3.

*35,36*—Undetermined cranidium no. 2. Dorsal and lateral views, ×5. Boulder 51 in Levis conglomerate at Levis, Quebec (USNM 143100).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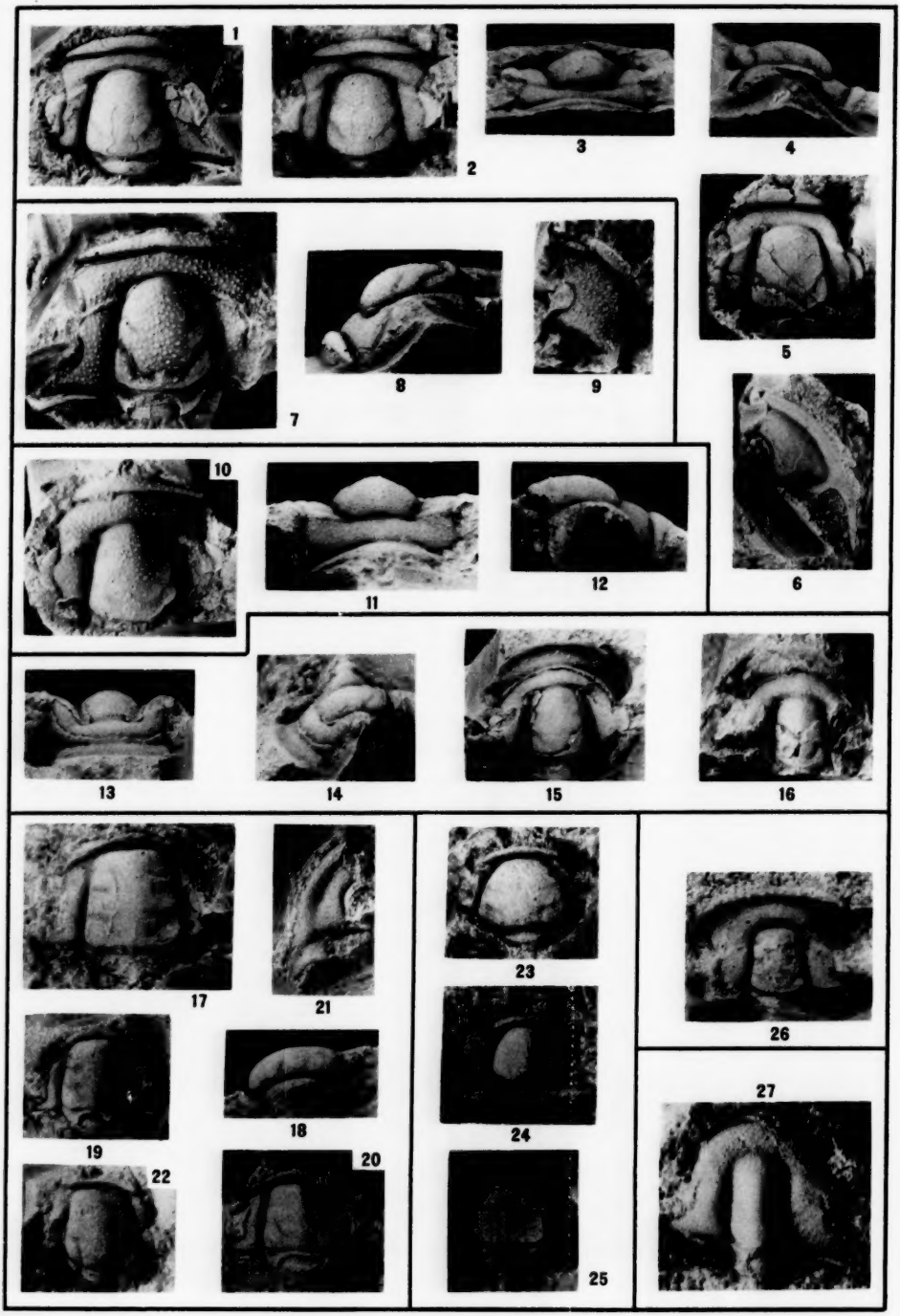
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of glabellar midpoint; palpebral area $\frac{2}{3}$ of glabellar width. Anterior facial sutures almost parallel; posterior section defining fairly slender, furrowed posterior area. Size very small.

*Occurrence.*—Quarry in Frederick (?) limestone, locality ccm/4.

*Disposition of material.*—Figured specimen: USNM 143102.

Undetermined pygidium no. 1
Pl. 25, fig. 23

Known from a single specimen. Entire pygidium with little relief. Axis tapered, well defined laterally, not reaching the posterior margin, extended into a postaxial ridge; four rings, plus the articulating ring and a terminal section well marked. Pleural lobes flat, with indistinct border furrow and border; anterior outline almost transverse, anterior angles moderately rounded, lateral margin curving backward and inward, extended into a pair of flat spines; 4 pairs of pleural furrows and vaguely defined interpleural grooves are present. In the specimen, apparently the right spine was broken during the life of the animal and left a scar. Length of pygidium 7 mm., width 13 mm.

This pygidium looks somewhat like those of *Crepicephalus*, but in view of the fact that several trilobites of different families possess such bispinose pygidia, any tentative assignment seems futile.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimen: USNM 143103.

Undetermined pygidium no. 2
Pl. 25, figs. 19,20

Represented by several individuals. Entire pygidium transverse, subelliptical; axis very prominent, tapered, reaching the slightly notched posterior margin, showing 4 rings and a terminal section. Pleural platforms slightly downsloping, showing 3 pairs of broad furrows and a trace of interplural grooves; border furrow wide and shallow, border flat, wider laterally than medially. Length of largest pygidium 4.2 mm.; width 7.8 mm.

One pygidium, seemingly belonging to this species, is attached to 12 thoracic

EXPLANATION OF PLATE 24

All the figured specimens represent the fauna of the *Dunderbergia* zone.

FIGS. *1–6*—*Dunderbergia simplex* Rasetti, n. sp. *1,4*, Dorsal and lateral views of cranidium preserving test, ×3. *2,3*, Dorsal and frontal views of cast from the natural mold of same specimen, ×3 (USNM 143067, holotype). *5*, Cranidium preserving test, ×2. *6*, Free cheek preserving test, ×2 (USNM 143068, paratypes). Loc. ccm/3.

*7–9*—*Dunderbergia* sp. cf. *D. variagranula* Palmer, ×2. *7,8*, Dorsal and lateral views of exfoliated cranidium. *9*, Exfoliated free cheek. Loc. ccm/3 (USNM 143066).

*10–12*—*Dunderbergia variagranula* Palmer. Dorsal, frontal, and lateral views of cranidium preserving test, ×5. Boulder 51 in Levis conglomerate at Levis, Quebec (USNM 143065, plesiotype).

*13–16*—*Pterocephalops acrophthalma* Rasetti, ×3. *13–15*, Frontal, dorsolateral, and dorsal views of cranidium preserving part of test; loc. ccm/3 (USNM 143087, plesiotype). *17*, Exfoliated cranidium; loc. ccm/4 (USNM 143088, plesiotype).

*17–22*—*Quebecaspis marylandica* Rasetti, n. sp. (all specimens preserving test, ×5). *17,18*, Dorsal and lateral views of cranidium (USNM 143089, holotype). *19,20*, Cranidia. *21*, Free cheek (USNM 143090, paratypes). Loc. ccm/3. *22*, Cranidium (USNM 143091); loc. ccm/4.

*23–25*—*Quebecaspis conifrons* Rasetti, n. sp., ×5. *23*, Exfoliated cranidium; loc. ccm/4 (USNM 143094, paratype). *24*, Cranidium preserving test; loc. ccm/3 (USNM 143092, holotype). *25*, Cranidium; loc. ccm/3 (USNM 143093, paratype).

*26*—Undetermined cranidium no. 3, ×5. Loc. ccm/3 (USNM 143101).

*27*—Undetermined cranidium no. 4, ×12. Loc. ccm/4 (USNM 143102).

segments. The anterior pleura are bluntly terminated, the posterior ones gradually develop a short, falcate extension which, in the last pair of pleura, envelops the sides of the pygidium.

The shape of the pygidium recalls *Loganellus* or *Levisella*, genera of younger (Trempealeau) beds. However, this is a type of generalized ptychoparioid pygidium occurring in a number of genera of widely different ages.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimens: USNM 143104.

Undetermined pygidium no. 3
Pl. 25, fig. 21

Known from a single specimen. Entire pygidium semicircular. Axis wide, elevated, tapered, reaching ⅔ of the pygidial length, showing the articulating ring, two prominent rings, and a terminal section. Pleural lobes with straight anterior outline, anterior angles barely rounded, remainder of margin of uniform curvature. Border furrow shallow, border narrow, slightly elevated. Pleural and interpleural furrows straight, visible at least on anterior portion of pleural lobes. Length of pygidium 3.6 mm., width 6 mm.

This might be the pygidium of one of the species of *Dunderbergia*, but definite evidence is lacking.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimen: USNM 143105.

Undetermined pygidium no. 4
Pl. 25, fig. 18

Known from a few specimens. Axis proportionately large, very prominent, tapered, rounded distally, reaching the border furrow, with 2 rings faintly indicated. Pleural lobes downsloping, showing 2 pairs of furrows and one of interpleural grooves. Border furrow and border poorly defined. Length of largest pygidium 2 mm., width 3.8 mm.

This is a type of pygidium common to a large number of Lower, Middle and Upper Cambrian generalized ptychoparioid genera, hence assignment is particularly difficult.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimen: USNM 143106.

Undetermined pygidium no. 5
Pl. 25, fig. 16

Known from a single specimen. Pygidium transversely subelliptical, with little relief. Axis narrow, short, rapidly tapered, extended into a long postaxial ridge that reaches the margin; 3 or 4 axial rings defined at least at the sides. Pleural lobes flat, with 4 pairs of regularly curved, broad, shallow furrows reaching the margin, no border furrow or distinct border. Length of pygidium 2.4 mm., width 4.4 mm.

This is an unusual type of pygidium and there is no indication for a possible assignment.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimen: USNM 143107.

Undetermined pygidium no. 6
P. 25, fig. 24

Known from 2 specimens. Pygidium very short and wide. Axis tapered, not much elevated above the pleural lobes, posteriorly merging with the border which forms a median notch; axial rings indistinct. Pleural lobes with 2 pairs of furrows separated by a pair of bosses; another pair of smaller and lower bosses posterior to the second pair of furrows. Border furrow well defined by the elevated border that forms a rim all around the pygidium. Length of pygidium 2.4 mm., width 5.6 mm.

There is no indication for a possible assignment of this curious pygidium.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimen: USNM 143108

Undetermined pygidium no. 7
Pl. 25, figs. 28–30

Known from several specimens of various sizes. Entire pygidium subelliptical. Axis very prominent, slightly tapered, extended into a postaxial ridge that reaches the margin, showing 4 prominent rings and a ter-

minal section. Pleural lobes downsloping; anterior outline slanted backward, anterior angles widely rounded, posterior outline regularly curved. Three or 4 pairs of furrows of decreasing depth die out before reaching the wide, undefined border furrow and narrow, flat border. Length of largest pygidium 7.5 mm., width 12 mm.

This pygidium must belong to a trilobite of fairly large size, and the fact that several specimens were found seems to indicate that it belongs to one of the more common cranidia from the locality. Possibly this is the pygidium of *Taenicephalites*.

*Occurrence.*—Loose blocks of Frederick (?) limestone at locality ccm/3.

*Disposition of material.*—Figured specimens: USNM 143109.

Undetermined pygidium no. 8
Pl. 25, fig. 17

Known from a complete specimen and several fragments. Pygidium approximately semicircular with well-rounded anterior angles. Axis short and wide, reaching half the pygidial length, prominent, abruptly terminated, extended into a faint postaxial ridge, showing 3 rings plus a terminal section. Pleural lobes slightly concave, not downsloping, showing two or three pairs of broad, shallow furrows. No distinct border furrow or border. Surface densely and finely granulated. Length of largest specimen 7.5 mm., width 12.5 mm.

*Occurrence.*—Quarry in Frederick (?) limestone, locality ccm/4.

*Disposition of material.*—Figured specimen: USNM 143110.

Undetermined pygidium no. 9
Pl. 25, fig. 22

Known from a single specimen. Pygidium weakly convex, wide and short, with fairly straight posterior margin. Axis rapidly tapered, with 3 rings and a terminal section, not quite reaching posterior margin. Pleural lobes slightly convex, with 4 pairs of furrows reaching the margin. No border furrow or border. Length 2 mm., width 4.4 mm.

*Occurrence.*—Quarry in Frederick (?) limestone, locality ccm/4.

*Disposition of material.*—Figured specimen: USNM 143111.

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## EXPLANATION OF PLATE 25

All the figured specimens represent the fauna of the *Dunderbergia* zone.

FIGS. *1–11*—*Taenicephalites macrops* Rasetti, n. gen., n. sp. *1–3*, Dorsal, lateral, and frontal views of small cranidium preserving test, ×5 (USNM 143095, holotype). *4,5*, Dorsal and lateral views of exfoliated cranidium, ×2. *6*, Exfoliated cranidium, ×2. *7,8*, Exfoliated cranidia, ×5. *9*, Partly exfoliated cranidium, ×2. *10*, Free cheek preserving test, ×5. Loc. ccm/3 (USNM 143096, paratypes). *11*, Poorly preserved cranidium, ×3; loc. ccm/4 (USNM 143097, paratype).

*12–15*—*Glyptometopsis? marginata* Rasetti, n. sp., ×5. *12–14*, Dorsal, frontal, and lateral views of cranidium preserving test. Boulder 51 in Levis conglomerate at Levis, Quebec (USNM 143074, holotype). *15*, Cranidium; loc. ccm/3 (USNM 143076, paratype).

*16*—Undetermined pygidium no. 5, ×5. Loc. ccm/3 (USNM 143107).

*17*—Undetermined pygidium no. 8, ×3. Specimen preserving test; loc. ccm/4 (USNM 143110).

*18*—Undetermined pygidium no. 4, ×5. Specimen preserving test; loc. ccm/3 (USNM 143106).

*19,20*—Undetermined pygidium no. 2. *19*, Small specimen with 12 thoracic segments attached, ×5. *20*, Specimen preserving test, ×3. Loc. ccm/3 (USNM 143104).

*21*—Undetermined pygidium no. 3, ×3. Specimen preserving test on pleural lobes; loc. ccm/3 (USNM 143105).

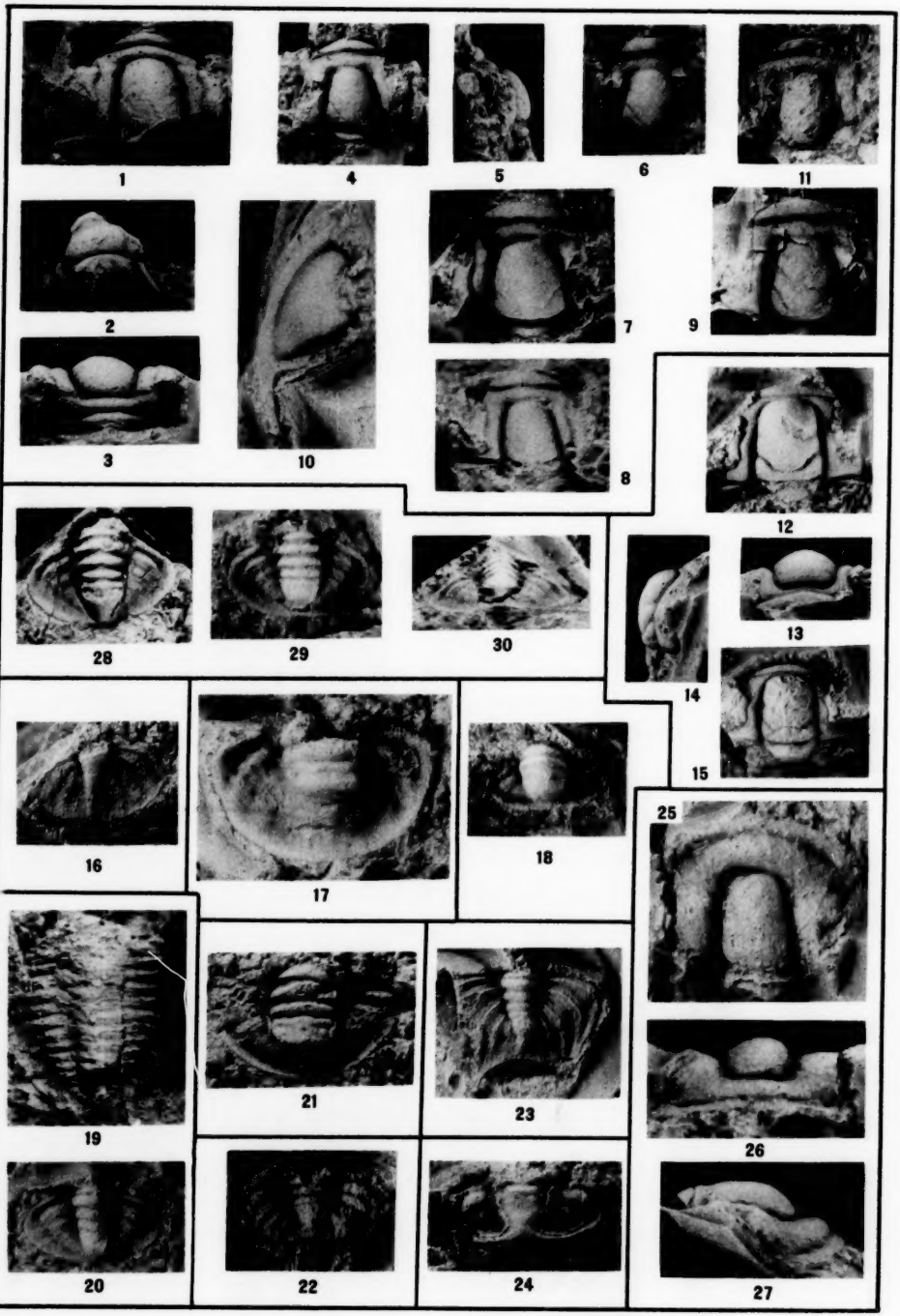
*22*—Undetermined pygidium no. 9, ×5. Loc. ccm/4 (USNM 143111).

*23*—Undetermined pygidium no. 1, ×2. Specimen preserving test; loc. ccm/3 (USNM 143103).

*24*—Undetermined pygidium no. 6, ×5. Specimen preserving portions of test; loc. ccm/3 (USNM 143108).

*25–27*—Undetermined cranidium no. 1, ×3. Dorsal, frontal, and lateral views of exfoliated specimen; loc. ccm/4 (USNM 143099).

*28–30*—Undetermined pygidium no. 7. *28*, Specimen preserving test on pleural lobes, ×2. *29,30*. Specimen preserving test on pleural lobes in dorsal and posterior views, ×3. Loc. ccm/3 (USNM 143109).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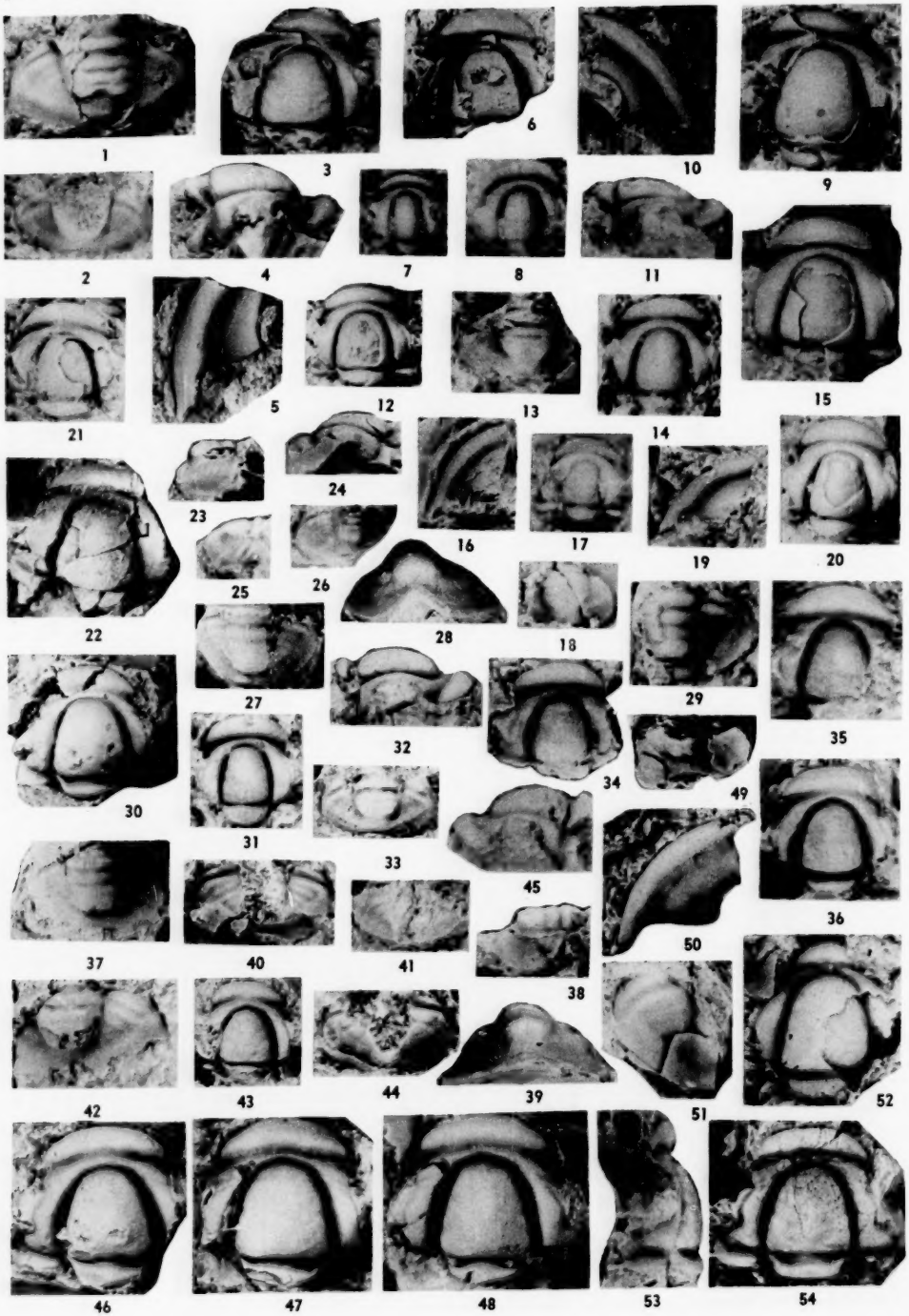

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# UPPER CAMBRIAN FAUNAS FROM THE NORTHWEST WIND RIVER MOUNTAINS, WYOMING. PART II

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ABSTRACT—The *Cedaria* zone faunules from the two measured sections near Green River Lakes in the northwestern Wind River Mountains, Wyoming contain 27 genera and at least 54 species of trilobites. The species of five families and a number of unplaced forms are described in this paper. The Asaphiscidae are represented by *Blountia* and *Vernaculina flexiosa*, n. gen., n. sp.; the Coosellidae by *Coosella vagrans*, n. sp., and two species of *Syspacheilus* including *S. praecedens*, n. sp., and *S. praecedens elongatus*, n. var.; the Marjumidae by three genera including *Shickshockia? occidentalis*, n. sp.; the Menomoniidae by two genera including *Densonella praesemele*, n. sp. and *D. praesemele transitans*, n. var.; and the Tricrepicephalidae with three species of *Meteoraspis*, including *M. intermedia*, n. sp. The new material has furnished much information about *M. globosa* (Miller), *M. boulderensis* DeLand and also *Syspacheilus dunoirensis* (Miller). *Densonella semele* and *Modocia centralis* range through 95 to 125 feet of section and appear as stable species indigenous to the Utah-Wyoming area. *Syspacheilus* and *Densonella* show significant evolutionary developments through their vertical range.

## EXPLANATION OF PLATE 26

FIGS. *1–25,27–36,40–48*—*Syspacheilus dunoirensis* (Miller). *1*, plesiotype, almost complete pygidium outer surface lost from axis, ×3, U.S.N.M. 137985h; *2*, smaller peeled pygidium, ×4.6, U.S.N.M. 137985g; *3,4*, dorsal, profile of largest cranidium, ×3, ×4, U.S.N.M. 137985c; *6*, a second smaller cranidium, ×2.3, U.S.N.M. 137985d; *7,8*, plesiotypes, smallest cranidium showing elongation of glabella, and next largest showing glabella broadening, ×8, U.S.N.M. 137985a,b; *5,16*, associated librigenae, ×2.7, ×2.2, U.S.N.M. 137985e,f, all from SM1. *9*, single cranidium from SM2a, ×5.3, U.S.N.M. 137986. *10,19*, plesiotypes, well preserved librigenae, ×4.7, ×3.2, U.S.N.M. 137987g,f; *17,14,20,15*, series of cranidia from 1.75 mm. to 4 mm. in length, ×6.7, ×11, ×6, ×6, U.S.N.M. 137987a,b,c,d; *11,12*, profile, dorsal of one of larger cranidia, ×3.2, U.S.N.M. 137987e; *18*, smallest pygidium, 1.25 mm. in length, ×7, U.S.N.M. 137987h; *13*, pleistotype, larger pygidium, ×6, U.S.N.M. 137987j, all from SM2. *21*, small cranidium with outer surface, ×3.5, U.S.N.M. 137988a; *22,24*, dorsal, profile of larger cranidium, ×2, U.S.N.M. 137988c; *29*, broken pygidium, ×4, U.S.N.M. 137988e; *23,27,28*, plesiotype, profile, dorsal, rear of large well preserved pygidium, ×1.5, ×1.5, ×2, U.S.N.M. 137988f, all from OC3. *31,43*, smallest cranidium, glabella slightly elongate, and larger cranidium, ×8, ×3.3, U.S.N.M. 137990a,b; *47*, dorsal, *45,46*, profile, dorsal, *48*, dorsal of three progressively larger cranidia, ×3, ×2.5, ×3, ×3, U.S.N.M. 137990c,d,e; *30*, largest cranidium, ×2.2, U.S.N.M. 137990h; *41*, fragmentary smallest pygidium, ×4.5, U.S.N.M. 137990f; *25,33*, plesiotype, profile, dorsal of small well preserved pygidium, ×3.4, U.S.N.M. 137990g; *40,42*, plesiotype, largest pygidium, showing doublure; rubber mold of impression of fig. *40*, to show axis, ×1.5, ×2.3, U.S.N.M. 137990i, all from OC4. *34,35,36*, series of small cranidia, 2 mm. to 3.25 mm. in length, ×8, ×5.4, ×6, U.S.N.M. 137989a–c; *44*, associated pygidium, axis broken but pleural regions well preserved, ×4.5, U.S.N.M. 137989d, all from 40-34.

*26,37–39*—*Syspacheilus dunoirensis* variety. *26*, a small pygidium 2 mm. in length showing expansion of postero-lateral part of border, ×4, U.S.N.M. 137991ax; *37,38,39*, dorsal, profile, rear of large pygidium showing same feature, ×1.9, ×1.9, ×2.1, U.S.N.M. 137991bx, from OC4.

*49–54*—*Coosella vagrans*, n. sp. *53,54*, profile, dorsal of holotype cranidium, ×2.1, U.S.N.M. 137992; *52*, paratype, rubber mold of an impression of another nearly complete cranidium, ×2.7, U.S.N.M. 137993a; *50*, paratype, associated librigena, ×2, U.S.N.M. 137993b; *49,51*, paratypes, associated fragments of pygidia, ×2, ×2, U.S.N.M. 137993d,c, from SM2.

## INTRODUCTION

*Cedaria* zone faunules were collected from both the Clear Creek section and the Sheep Mountain section. The location and the lithology of these sections were described in detail in Part I (Lochman and Hu, 1960). Most collections were from the DuNoir limestone, a 125 foot cliff-forming unit of gray, coarsely crystalline, occasionally oolitic, mottled limestones, thin-bedded dense argillaceous limestone and flat or edgewise limestone pebble conglomerates intercalated with thin shale partings.

Two faunules assigned to the base of the upper *Cedaria* subzone were obtained from the lowest exposed beds in the Clear Creek section. One assemblage appears to be an in situ association on an algal reef, the other assemblage occurs in the reef flank debris. The *Cedaria* zone occurs through at least 135 feet of the DuNoir limestone and uppermost subjacent Park shales in the Sheep Mountain section. Most beds are quite fossiliferous and the collections are closely spaced vertically with the exception of a 57 foot barren interval between 8 and 65 feet below the top of the DuNoir. The faunules from the upper 8 feet belong to the base of the upper *Cedaria* subzone and are similar to those of the same age from the Clear Creek section. The faunules of the middle *Cedaria* subzone range from 65 to 117 feet below the top of the DuNoir. Faunules through the underlying 15 feet are referred to the top of the lower *Cedaria* subzone because of the presence of *Bolaspidella*.

## ACKNOWLEDGMENTS

The authors wish to thank Drs. C. L. Baker, F. E. Turner and G. M. Richmond for the invitation to the senior author to visit the area, their continued cooperation during the field work, and for furnishing previously collected material and information from G. E. Gulmon. The completion of the study was made possible by a Research Assistantship Grant to the junior author from the New Mexico Institute of Mining and Technology.

## DESCRIPTION OF FOSSIL HORIZONS

The fossil horizons are indicated by a combination of letters and numbers for the senior author's collections, and by a combination of numbers alone for the collections made by Gordon Gulmon in 1939. Several collections made by F. E. Turner are so indicated. The horizons are arranged in descending stratigraphic order for each of the sections. The types and figured specimens are deposited at the United States National Museum. Duplicate material is at the New Mexico Institute of Mining and Technology.

### CLEAR CREEK SECTION

| | |
|---|---|
| OC3—118 to 120 feet below top of DuNoir limestone<br>OC4—127 feet below top of DuNoir limestone (Turner-40-34) | Base of upper *Cedaria* subzone |

### SHEEP MOUNTAIN SECTION

| | |
|---|---|
| 39–54—at top of DuNoir limestone<br>39–50—1 foot below top of DuNoir limestone<br>SM1—5 feet below top of DuNoir limestone<br>SM2—6.5 feet below top of DuNoir limestone<br>SM2a—7.5 feet below top of DuNoir limestone | Base of upper *Cedaria* subzone |
| SM3—65 feet below top of DuNoir limestone<br>SM4—89 feet below top of DuNoir limestone<br>SM5—92 feet below top of DuNoir limestone<br>SM6—94.5 feet below top of DuNoir limestone<br>SM7—95.5 feet below top of DuNoir limestone<br>SM8—97 feet below top of DuNoir limestone<br>SM8a—97.5 feet below top of DuNoir limestone | Middle *Cedaria* subzone |
| 38-4—105 feet below top of DuNoir limestone<br>39-51—117 feet below top of DuNoir limestone<br>SM10—120 feet below top of DuNoir limestone | Lower *Cedaria* subzone |

DISCUSSION OF THE FOSSILS

The Asaphiscidae are represented by two genera, *Blountia* and a new genus, *Vernaculina*. *Blountia carlotta* is a normal member of the local biota. The large numbers of specimens are indistinguishable from the Montana type material in the cranidium. Most of the pygidia show 7 to 8 axial rings, a variation also present in Montana. At OC3 the species is represented by equal numbers of cranidia and pygidia; but at OC4, the reef-flank coquina, at least 44 pygidia but only 2 small cranidia were obtained. This distribution is interpreted as indicating that *B. carlotta* inhabited the shallow algal reefs and that most of the molts were washed into the reef flanks where the flat pygidia settled more readily than the convex cranidia. DeLand obtained cranidia and also pygidia (erroneously named *Kingstonia*) of *B. carlotta* from Steele Butte. The broad-bordered pygidium, incorrectly associated with this species, appears to represent the same form as the two pygidia from Montana described as *B.* aff *B. janei* Lochman. *Vernaculina flexiosa*, new species, the genotype, shows a close relationship to *Asaphiscus* in structure of both cranidium and pygidium; but the shorter broader glabella, narrower fixigenae and shorter more transverse pygidium are easily recognized distinctions. The species ranges through 10 feet of the upper half of the lower *Cedaria* subzone. Miller (1936) figured a pygidium of *Vernaculina* associated with *Syspacheilus dunoirensis* near DuNoir, Wyoming. The latter species appears in the Sheep Mountain section 85 feet above the last appearance of *V. flexiosa*. Basic structural differences in cranidium and pygidium distinguish *Vernaculina* from the much younger *Coosia*. The faint similarities of the exoskeletons of *Asaphiscus* and *Vernaculina* to that of *Coosia* are attributed to homoeomorphy.

The Coosellidae are represented by *Syspacheilus* and *Coosella*. *Syspacheilus* ranges through more than 100 feet of the Sheep Mountain section and is known from many specimens of two related species, both normal members of the local biotas. *S. praecedens*, n. sp. ranges through 32 feet of the lower *Cedaria* subzone; and in structure as well as stratigraphic position appears to be the ancestor of *S. dunoirensis*. For both species at each horizon there is a constant association of cranidium and the type of pygidium shown on pl. 1, figs. 1, 2. The authors are confident that at last the correct pygidium and also the librigenae are associated with the *Syspacheilus* cranidia. This pygidium, like the cranidium, is primitive in that it approaches the basic ptychoparid pygidium in shape. Coosellid trends are present in the low short post-axial ridge and a median upbend (instead of inbend) of the posterior margin. In *S. praecedens* the upbend is just appearing. In *S. dunoirensis* the upbend is very pronounced and at the highest horizons the larger pygidia show a widening of the border which translates the upbend into a posterior median inbend when viewed from above. The long range and individual abundance and variation of *Syspacheilus* in this material suggests that this indigenous genus evolved from its late Middle Cambrian ancestor within the Wyoming seaways. *S. praecedens* appears as the ancestor of both *S. dunoirensis* and *S. camurus* Lochman of Montana and Wyoming. The several hundred specimens of *S. dunoirensis* illustrate very well the amount of individual variation which may occur within the species. Several varieties are shown on plate 1. Individual variations were also noted in the populations of *S. praecedens* showing trends in the direction of *S. dunoirensis*. *Coosella* is known only from a few cranidia and pygidia which are so distinctive as to warrant a new species, *C. vagrans*. The species shows some similiarites to *C. beltensis* Lochman from Montana and occurs only in the basal faunule of the upper *Cedaria* subzone, SM2. *Coosella* first appears in Montana at this position also, and would appear to have just evolved at this time presumably from *Syspacheilus* in response to a more specialized habitat.

The Marjumiidae are represented by *Modocia*, *Talbotina* and *Shickshockia*. *Modocia centralis* (Whitfield) ranges through 125 feet of section and reaches its peak in SM6, near the top of the lower *Cedaria* subzone. It is moderately abundant in all collections except those at the top, SM1

and SM2, from which only a few fragments were obtained. The species is believed to have been indigenous to the area of northern Wyoming, southern Montana and east to the Black Hills. There is little variation in the populations during the entire time range. Only in SM6 is a cranidial variant noticeable. On some cranidia there is a single row of granules on the preglabellar field and the anterior border is relatively wide. The type of pygidium which Palmer (1954) first described with the cranidium is regularly associated with cranidia in these collections. *Talbotina jeweli*, described from the upper part of the middle *Cedaria* subzone at Nixon Gulch, Montana, is known here from six cranidia in the lower part of the middle *Cedaria* subzone. The species is not a normal inhabitant of this region as the few specimens have been transported some distance, but its brief appearance is important as it extends the biozone of the species. Four pygidia are referred to *Shickshockia? occidentalis*, new species. The holotype, though only one-fourth the size of Rasetti's types of *S. cristata* from the western Gaspé, is similar in shape, basic structure and even small details. The genus occurs in extracratonic assemblages and is believed to have been a normal inhabitant of miogeosynclinal areas. These few specimens were transported some distance eastward into the unstable shelf sites of western Wyoming.

The gonatoparian Menomoniidae are represented by *Bolaspidella* and *Densonella*. Five worn fragmentary cranidia from SM10 are referred to *B. wellsvillensis*. Specific

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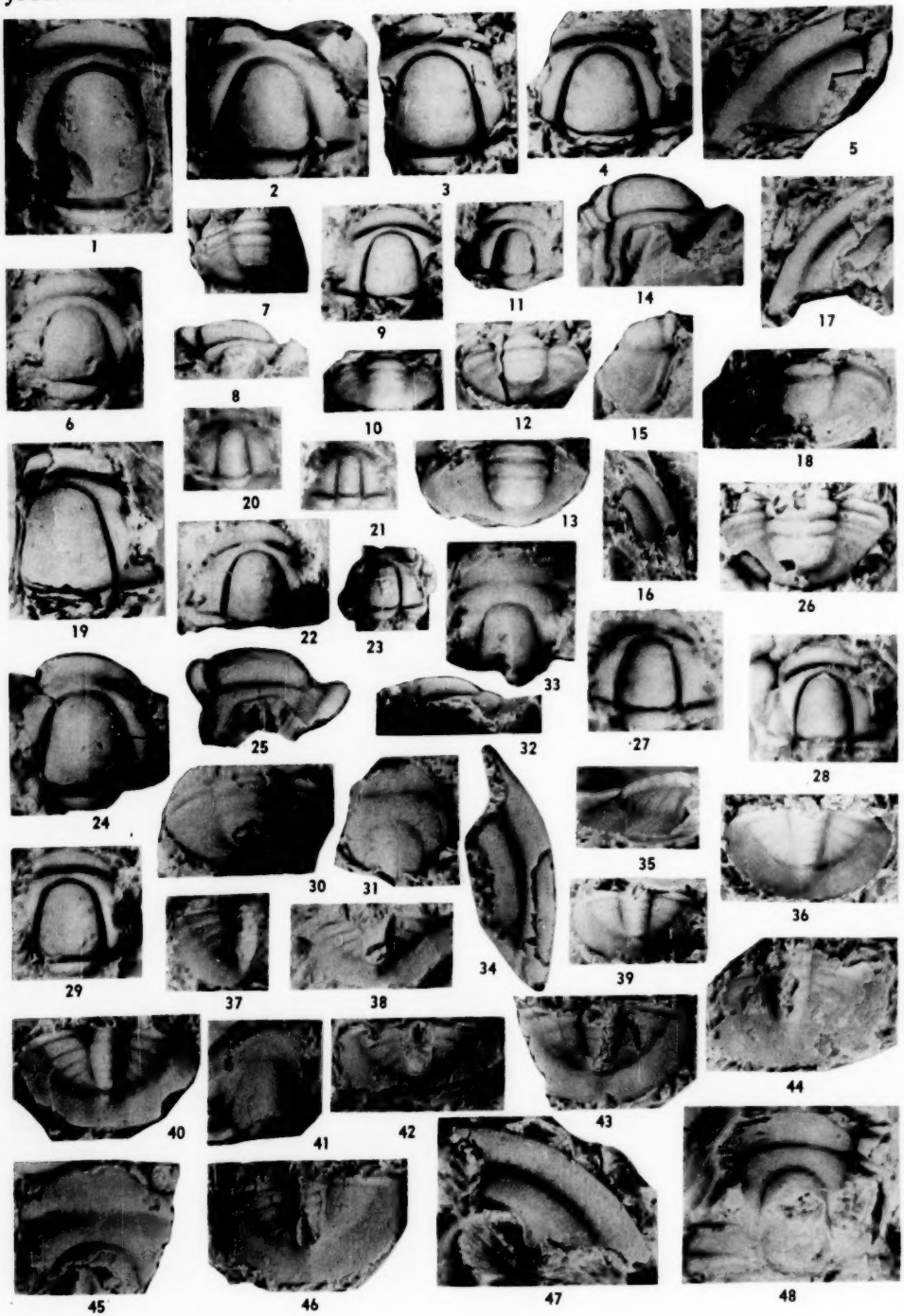
EXPLANATION OF PLATE 27

FIGS. *1–18,29—Syspacheilus praecedens*, n. sp. *4,14*, holotype, dorsal, profile of nearly complete cranidium with anterior margin broken, ×3.8, ×4, U.S.N.M. 137994; *11,9*, paratypes, small cranidia (2.2 mm. and 3 mm.), with lateral furrows noticeable, ×6, ×5.5, U.S.N.M. 137995b,c; *3,2*, paratypes, medium-sized peeled and unpeeled cranidia, ×5, ×5.5, U.S.N.M. 137995d,f; *1*, paratype, large broken cranidium, ×3.4, U.S.N.M. 137995g; *5,17*, paratypes, associated librigenae with short blunt genal spines, ×3.5, ×6, U.S.N.M. 137995i,h; *12*, paratype, medium-sized pygidium, ×3, U.S.N.M. 137995k; *15,18*, paratype, profile, dorsal of large pygidium, ×4.3, U.S.N.M. 137995m, all from SM6. *6,8*, dorsal, profile of cranidium from SM3 showing variation in direction of *S. dunoirensis*, ×3.3, U.S.N.M. 137998. *7*, broken pygidium with good outer surface, ×2.4, U.S.N.M. 137996b; *10*, a small (0.65 mm.) pygidium, ×14, U.S.N.M. 137996a, both from SM8. *13,16*, a pygidium and a librigena from SM8a, ×3.5, ×2.5, U.S.N.M. 137997a,b. *29*, a cranidium from 39–50 showing variation towards *S. dunoirensis*, ×5, U.S.N.M. 138003.

*19–28,30—Syspacheilus praecedens* var. *elongatus*, n. var. *19*, paratype, cranidium, U.S.N.M. 138000f; *20*, paratype, a meraspid cranidium (0.875 mm.), granular surface noticeable, ×15, U.S.N.M. 138000a; *21*, paratype, small holaspid cranidium (1.25 mm.) with similar granular surface, ×8.5, U.S.N.M. 138000b; *23*, paratype, small broken cranidium, ×4, U.S.N.M. 138000c; *24,25*, paratype, dorsal, profile of larger peeled cranidium, ×4, ×4.2, U.S.N.M. 138000e; *22*, holotype, nearly complete cranidium with well preserved outer surface, ×3, U.S.N.M. 137999; *26*, paratype, pygidium showing small spine on anterior segment, ×3.5, U.S.N.M. 138000n; *30*, paratype, a second pygidium, ×3.5, U.S.N.M. 138000o, all from SM6. *28*, a small cranidium from SM8, ×6, U.S.N.M. 138001. *27*, a small cranidium (1.875 mm.) with elongate glabella and 3 pairs of lateral furrows quite distinct, ×14, U.S.N.M. 138002, from SM8a.

*31–48—Vernaculina flexiosa*, n. gen., n. sp. *48*, holotype, a medium-sized cranidium, ×4, U.S.N.M. 138004; *32,33*, paratype, profile, dorsal of smaller cranidium, ×2, U.S.N.M. 138005a; *31*, paratype, mold of fragment of larger cranidium, ×1.7, U.S.N.M. 138005c; *41*, a worn fragmentary cranidium, ×3.5, U.S.N.M. 138005b; *34,37*, paratypes, two large associated librigenae, ×2.8, U.S.N.M. 138005d,e; *35,36*, paratype, profile, dorsal of nearly complete pygidium with worn surface, ×2.5, ×2, U.S.N.M. 138005h; 42,43, paratypes, two more pygidia showing breakage and wear, ×2.6, ×2.1, U.S.N.M. 138005f,g, all from SM6. *45*, fragment of cranidium, ×2.7, U.S.N.M. 138008a; *44,46*, two associated pygidia showing surface well worn, ×2, ×1.8, U.S.N.M. 138008b,c, from SM5. *37,38*, two small pygidia from SM7, ×4, U.S.N.M. 138006b,a; *39,40*, paratypes, a small pygidium and the largest pygidium obtained, note well preserved outer surface on these specimens, ×2.7, ×1.7, U.S.N.M. 138007b,a, from SM8a.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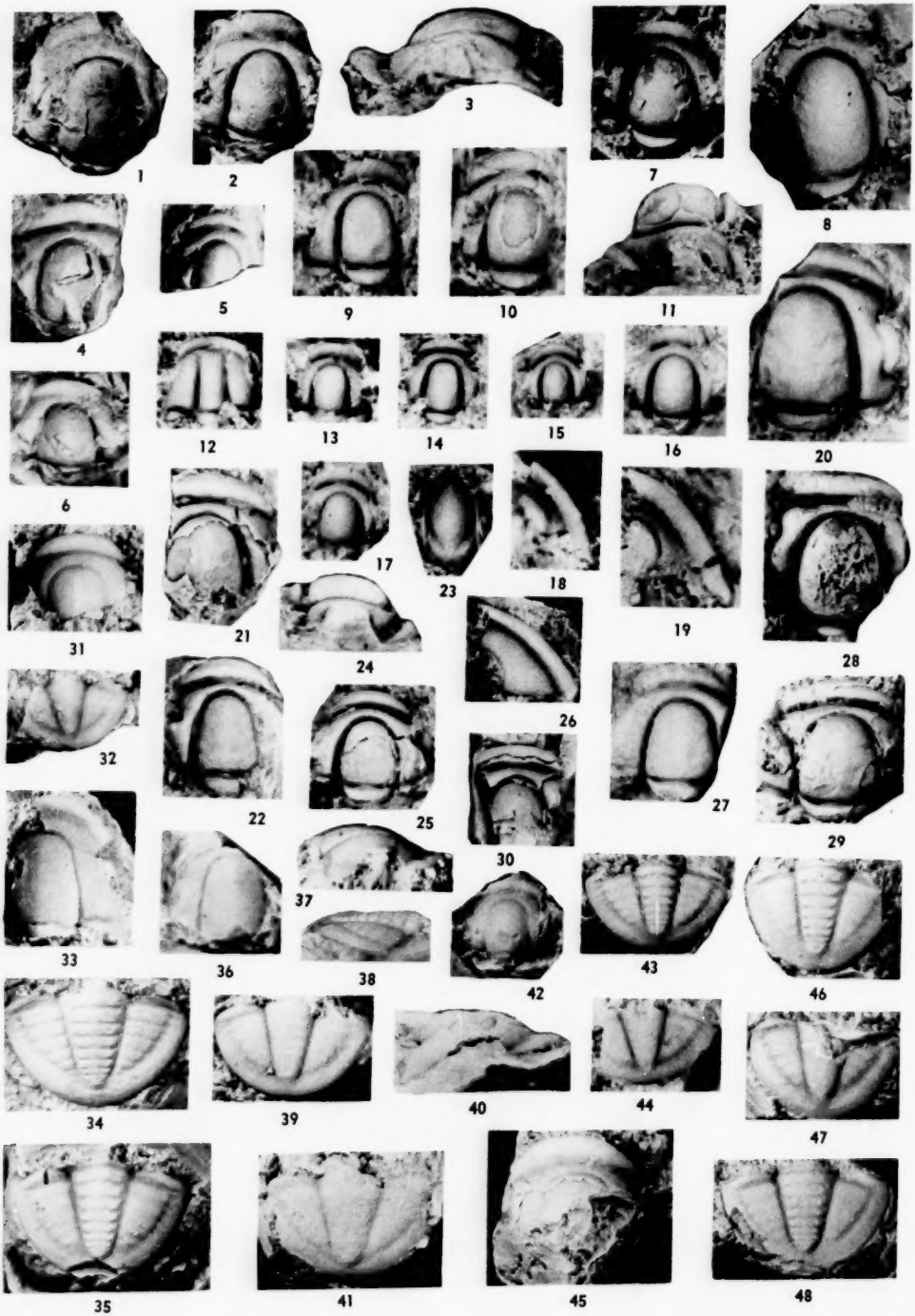
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identification is certain for two of the specimens but the amount of wear affects the appearance of the others.

These specimens may have been reworked from a lower horizon. Several small broken cranidia from SM2 and SM3 are tentatively referred to *Bolaspidella*. The position is much higher stratigraphically than any previously reported for the genus, yet all determinable features of the fragmentary specimens appear to indicate *Bolaspidella*. *Densonella* ranges through almost 125 feet of the section. Its abundance and individual variations mark it as another normal member of the local biota, evolving in situ during *Cedaria* zone time. *Densonella semele* (Walcott) was described from the House Range, Utah and the species ranges through 95 feet of the Wyoming section. Cranidia and librigenae up to 7 mm in length indicate a larger size than previously known. On well preserved outer surfaces the granules are seen to be arranged in longitudinal rows on the exoskeleton with two rows running the length of the axis of the body. Small pygidia with distinctive granular ornamentation can be associated with the cranidia. The continuous presence of specimens permits recognition of a continuity of lineage between *D. semele* and forms occurring in lower horizons. The lowest *D. semele* is recorded from SM6. In SM7, one foot lower, two types of cranidia occur. In one group (which ranges down to SM8) the eyes are stalked, but the frontal area is consistently wider than that in *D. semele*. This cranidial type appears to be a transitional variety between *D. semele* and the second, more abundant

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EXPLANATION OF PLATE 28

FIGS. *1–6—Meteoraspis intermedia*, n. sp. *2,3*, holotype, dorsal, profile of largest cranidium, ×1, ×1.5, U.S.N.M. 137973; *1*, paratype, weathered cranidium, ×1.3, U.S.N.M. 137974b; *5*, paratype, fragmentary small cranidium, ×7, U.S.N.M. 137974d; *4*, paratype, cranidium with well preserved frontal area, ×1.8, U.S.N.M. 137974c; *6*, paratype, small cranidium sagitally compressed, ×3, U.S.N.M. 137974a, from OC3.

*7–19—Meteoraspis globosa* (Miller). *7,11*, plesiotype, dorsal, profile of small cranidium with median pit in anterior furrow, ×3, ×3.4, U.S.N.M. 137975b; *8*, plesiotype, largest cranidium, ×2.8, U.S.N.M. 137975a, both from SM2; *12*, meraspid cranidium, ×19, U.S.N.M. 137976h, OC4; *13–17*, series of small holaspid cranidia from 1.5 to 2.75 mm. in length, ×8.3, ×8.3, ×5.5, ×5.5, ×5.5, U.S.N.M. 137975f, 137976l, 137975g,d,e, from SM2, OC4, SM2, SM2, SM2; *9,10*, two small cranidia, 3.75 and 3 mm. in length, ×6, ×7.3, U.S.N.M. 137975c, 137976i, from SM2, OC4; *18,19*, two small librigenae showing very short genal spine, ×10, U.S.N.M. 137976j, 137975k, from OC4, SM2.

*20–29—Meteoraspis boulderensis* DeLand. *21*, fragmentary cranidium, ×5.3, U.S.N.M. 137978, from SM2; *25,22,27*, plesiotypes, three small cranidia showing variations caused by individual differences and preservation, ×5.5, ×4.5, ×5.3, U.S.N.M. 137977a,b,c; *20,24*, dorsal, profile, of cranidium showing normal proportions, faint median pit on anterior furrow and fine granulation on surface, ×5, ×3.8, U.S.N.M. 137977d; *29*, plesiotype, cranidium 9 mm. in length showing slight sagittal compression as in the holotype, ×2.4, U.S.N.M. 137977e; *23*, plesiotype, hypostoma, ×3.3, U.S.N.M. 137977h; *26*, plesiotype, associated librigena, ×1.6, U.S.N.M. 137977i; *28*, rubber mold of impression of cranidium 13 mm. in length, ×2, U.S.N.M. 137977f, from OC4.

*30*—cf. *Meteoraspis* sp. undet. Fragment of small cranidium with pair of pits in anterior border furrow, ×4, U.S.N.M. 137984, from SM8a.

*31–48—Blountia carlotta* Lochman. *31*, broken cranidium, ×5.2, U.S.N.M. 137980a; *32*, associated pygidium, ×5, U.S.N.M. 137980b, from SM1; *44*, anterior fragment of cranidium, ×5.2, U.S.N.M. 137979, from SM2; *42*, small well preserved cranidium, ×3.2, U.S.N.M. 137981b; *40,45*, profile, dorsal of large cranidium, ×2.1, U.S.N.M. 137981a; *41,47*, two associated pygidia, ×3, ×4.4, U.S.N.M. 137981d,c, all from OC3; *33,37*, dorsal, profile of a cranidium, ×4.9, U.S.N.M. 137983a; *34,38*, dorsal, profile of peeled pygidium, ×3, U.S.N.M. 137983b; *35*, a smaller peeled pygidium, ×3, U.S.N.M. 137983c; *39*, pygidium with good outer surface, ×4, U.S.N.M. 137983d, all from 40-34; *36*, broken cranidium, ×4.7, U.S.N.M. 137982d; *43*, small peeled pygidium, ×2.8, U.S.N.M. 137982a; *48*, pygidium with outer surface, ×2.7, U.S.N.M. 137982b; *46*, largest pygidium, ×1.8, U.S.N.M. 137982c, all from OC4.

group which is recognized as a distinct species, *D. praesemele*, new species, ranging downward through 30 feet of the section. In this new species the glabella is proportionately shorter and broader than in *D. semele*, the frontal area wider (tr), and the palpebral areas, though still strongly convex and upsloping, have the palpebral lobes in horizontal position so that the adult eyes are not truly stalked. There is no distinction in the associated pygidia. The mode of life of *Densonella* apparently favored genetic variations toward greater and greater elevation of the eye. The older normal type, *D. praesemele*, was superseded by the specialized *D. semele*. Utah and western Wyoming is believed the indigenous site of this evolution. *D. praesemele* is known from Texas by a cranidium originally referred to *Bolaspidella* (Palmer, 1954, pl. 83, fig. 9). At a lower horizon Palmer obtained cranidia of another type, *Bolaspidella prooculis* Palmer. This species clearly belongs to *Bolaspidella* in the structure of the fixigenae and the frontal area but differs from all typical *Bolaspidella* species in the anterior position of the palpebral lobes and the convexity of the palpebral areas. It is possible that this species represents the variant of *Bolaspidella* which became the monophyletic ancestor of *Densonella*.

*Meteoraspis* is the only member of the Tricrepicephalidae present. This is an unusual situation as *Tricrepicephalus* ranges throughout the Dresbachian in the Weeks formation, House Range, Utah and is present but not especially common in the Montana sections. *Meteoraspis* occurs only in the highest collections placed in the base of the upper *Cedaria* subzone and does not appear to have become established in the local biota. The small numbers of specimens representing the three species have all been transported. The species seem to be local Wyoming forms which resemble one or another of the Montana or Texas species but cannot actually be identified with any of them. *Meteoraspis globosa* (Miller), represented by a number of small cranidia, but only one large cranidium and no pygidia, was described from the northeast Wind River Mountains. In shape of glabella and proportions of frontal area the species resembles *M. elongata* Lochman, but only *M. metra* (Walcott) has as convex a glabella. *M. boulderensis* DeLand was described from Steele Butte and the additional cranidia, librigenae and hypostoma considerably increase our knowledge of this species, which is similar to *M. keeganensis* Duncan from Montana. Population studies of the two named forms may show them to be variants of the same species, but at present there is not enough material available from either region. Nine cranidia from OC3 are described as a new species, *M. intermedia*. The form resembles *M. robusta* Lochman from Montana but the slopes of the preglabellar field and anterior border are much lower than usual for *Meteoraspis*, and the faint median pit on the border furrow is present in all specimens rather than rarely (Palmer, 1954). In these respects *M. intermedia* varies in the direction of *Tricrepicephalus*.

The Norwoodiidae are represented by *Holcacephalus tenerus*, described in part 1 and a single cranidium and pygidium assigned to *Norwoodella*. The specimens must have been transported a considerable distance. The very limited occurrence of *N. simplex* in the Montana faunas also would suggest that the Cordilleran shelf areas were not the normal environment for this genus. The great abundance of *Norwoodella* in the Nolichucky shales of the southern Appalachians suggests either warmer waters or an extracratonic habitat for the genus.

A number of cranidia and pygidia known only from one or two specimens are figured, but they do not merit description as new species. This practice was first adopted by Rasetti (1944, 1945) and has proven useful stratigraphically. It places the specimens on record so that when additional specimens from other collections provide an accurate identification, the earlier information on the species is available. One form, represented by three fragmentary cranidia, is named cf. *Liostracina* sp. to call attention to it. The cranidia, all 1 mm in length, are unique among Upper Cambrian Cordilleran shelf species in possessing a longitudinal median furrow on the preglabellar field. The form must belong actually to the western miogeosynclinal assemblages. *Liostracinoides* Raymond from the Lower Gorge fauna of Vermont (at least upper Franconian in age)

is the only known North American genus with this feature. *Liostracina* occurs in the Kushan formation of eastern Asia. The Kushan fauna was long considered latest Middle Cambrian, but has recently been moved to the basal Upper Cambrian (Lu, 1956).

## SYSTEMATIC DESCRIPTIONS

Phylum ARTHROPODA
Class TRILOBITA
Order PTYCHOPARIIDA
Family—ASAPHISCIDAE
Subfamily—ASAPHISCINAE

### VERNACULINA, new genus

Cranidium elongate-rectangular, convexity low, glabella low, tapered forward slightly rounded or nearly straight front, no lateral furrows, other furrows narrow, shallow, frontal area about 0.3 cranidial length (sag), fixigenae horizontal, palpebral areas 0.3 to 0.5 of glabellar width, palpebral lobes medium size or under, opposite or slightly anterior to glabellar center, posterior areas narrow (exsag), about same length (tr) as occipital ring. Librigenae elongate, narrow convex ocular field, broad lateral border furrow, medium-width lateral border with short to medium-length genal spine. Pygidium broad-transverse, convexity low, axis narrower than pleural fields, tapered to narrow rounded end, 5 to 6 axial rings and pleurae, interpleural grooves distinct, pleural furrows faint to obsolete, border furrow broad, shallow, border of medium width all around, downsloping. Outer surface smooth.

Genotype: *Vernaculina flexiosa*, n. gen., n. sp.

### VERNACULINA FLEXIOSA, n. sp.
Pl. 27, figs. 31–48

Cranidium elongate-rectangular, glabella low, tapering to slightly rounded front, lateral furrows obsolete, dorsal and occipital furrows narrow, shallow, occipital ring flat, frontal area 0.3 length of cranidium, preglabellar field downsloping, slightly narrower (sag) than the flat to slightly concave anterior border, anterior border furrow shallow, narrow; fixigenae flat, horizontal, no eye ridges, palpebral areas just over 0.3 of glabellar width, palpebral lobes under medium size, anterior to glabellar center, posterior areas narrow (exsag), strap-like, almost same length (tr) as occipital ring, posterior furrow broad, shallow. Librigenae elongate, ocular field narrow, downsloping, broad shallow lateral border furrow, medium-wide, slightly convex lateral border with genal spine apparently of medium length.

Pygidium broad-transverse, axis slightly convex, narrower than pleural fields, tapered 0.66 of length to narrow rounded end with low post-axial ridge continuing onto border, 5 axial rings and terminal separated by narrow interpleural grooves, pleural furrows obsolete or only as shallow slits at border furrow, border furrow broad, distinct, border flat, same medium width all around, downsloping.

Outer surface apparently smooth, caecal venations on inner surface of preglabellar and ocular fields of cephalon.

*Remarks.*—This form appears to represent one of the latest genera of the Asaphiscinae which are characteristic of the upper half of the Middle Cambrian in the Cordilleran region. It differs from *Asaphiscus* in the shorter, broader shape of the tapering glabella, the narrower horizontal palpebral areas and the narrower, more elongate posterior areas. In the pygidium the basic structure is the same, the narrow axis tapered to the border with a low post-axial ridge, and the border maintaining the same width posteriorly and laterally; but the genus differs in that there are only 5 axial rings and pleurae rather than 8 to 9, and in shape the pygidium is consequently shorter and more transverse rather than almost semicircular.

A faint similarity is suggested between *Vernaculina* and the much later *Coosia*, but basic structural differences exist both in the shape of glabella and frontal area of the cranidium and all parts of the pygidium. The faint similarities are believed caused by homoeomorphy as a result of this form being adapted to the same or a very similar habitat as that later occupied by *Coosia*.

The fragmentary cranidia and the better preserved pygidia indicate that the species reached medium-sized dimensions. The transverse pygidia transported with much less breakage than the narrow cranidia. The species ranges through about 10 feet of the

lower part of the Sheep Mountain and at present it cannot definitely be stated whether this represents nearly its entire biozone, or simply the time of its most eastward invasion of the Wyoming seas.

B. M. Miller (1936) figured a pygidium (pl. 8, fig. 27) which he associated with cranidia of *Syspacheilus dunoirensis*. This pygidium belongs also to *Vernaculina*, but may represent another species. It occurs with *S. dunoirensis*, a species of *Syspacheilus* characteristic of a higher *Cedaria* zone faunule than that in which *Vernaculina flexiosa* occurs.

This species is known from about 25 specimens in the four horizons.

*Horizon and locality.*—SM5, SM6, SM7, SM8a.

*Types.*—paratypes, cranidium, U.S.N.M. 138008a, pygidia, U.S.N.M. 138008b,c (SM5); *Holotype*, cranidium, U.S.N.M. 138004, paratypes, cranidia, U.S.N.M. 138005a,b,c, librigenae, U.S.N.M. 138005d,e pygidia, U.S.N.M. 138005f,g,h (SM6); paratypes, pygidia, U.S.N.M. 138006a,b (SM7); paratypes, pygidia, U.S.N.M. 138007a,b, cranidium, U.S.N.M. 138007 (SM8a).

Subfamily BLOUNTIINAE

BLOUNTIA CARLOTTA Lochman

Pl. 28, figs. 31–48

*Blountia carlotta* Lochman in Lochman and Duncan, 1944, p. 84–85, pl. 11, figs. 28–31.

*Blountia carlotta* Lochman, DeLand and Shaw, 1956, p. 548, pl. 63, figs. 3–7 (not fig. 8).

*Kingstonia* sp. undet., DeLand and Shaw, 1956, pl. 63, fig. 16.

*Remarks.*—This species is moderately well represented at the two Clear Creek localities, OC3 and OC4. At OC3 9 pygidia and 8 cranidia were obtained from the dense reef type limestones, while at OC4 at least 44 pygidia, ranging in size from 12 mm down to 2.5 mm. in length, and only two small cranidia were obtained. In collections SM2 and SM1 in which the fossil material has been moderately well sorted, only 2 pygidia and a small broken cranidium, and 2 pygidia respectively, have been found. This distribution, coupled with the structureless limestone at OC3, suggests that *Blountia* was a reef-dweller and that in the localities away from OC3 only disarticulated portions of the exoskeleton are deposited. OC4 is situated on the reef flanks, and into this area the flat, disc-like pygidia would easily float and settle. The Sheep Mountain localities are several miles from OC3 and the material reaching that area had been sorted to a small, more rounded shape, and most of the flat pygidia had settled out on the flanks of the reef.

The specimens in OC4 show much better surface preservation than in OC3, where some recrystallization has damaged both the outline and the surfaces. The specimens of this species show little variation when compared to the type material from the one Montana locality, Nixon Gulch, horizon 2.3. No variation in cranidium can be detected. In the pygidia the Wyoming specimens all show only 7 to 8 axial rings whereas on the Montana specimens 7 to as many as 9 axial rings can be detected with the latter number being the more common. This similarity of geographic populations, coupled with the association of the species at both localities with *Ankoura*, *Kingstonia*, *Arapahoia* and closely related species of *Cedaria*, indicates that the assemblage is controlled by a particular habitat.

DeLand obtained this species at Steele Butte, 45 miles farther to the south. At this locality he erroneously associated a broad-bordered pygidium (1956, pl. 63, fig. 8) with the cranidia of *B. carlotta* and figured (pl. 63, fig. 16) the correct pygidium as a *Kingstonia*. The broad-bordered pygidium apparently represents the same species as the two pygidia from Montana described as *B.* aff. *B. janei* by Lochman and Duncan, 1944, pl. 11, figs. 11,12.

*Horizon and locality.*—OC3, 39–50, OC4, 40–34, SM1, SM2.

*Figured specimens.*—cranidium, U.S.N.M. 137982d, pygidia, U.S.N.M. 137982a,b,c (OC4); cranidium, U.S.N.M. 137983a pygidia, U.S.N.M. 137983b,c,d (40–34); cranidia, U.S.N.M. 137981a,b, pygidia, U.S.N.M. 137981c,d (OC3); pygidium, U.S.N.M. 137980b; cranidium, U.S.N.M. 137980a, (SM1); pygidium, U.S.N.M. 137979 (SM2).

Family COOSELLIDAE

COOSELLA VAGRANS, n. sp.

Pl. 26, figs. 49–54

Cranidium with slightly convex, broad glabella, sides tapering to rounded front,

lateral furrows faint, dorsal and occipital furrows deep, occipital ring of medium width, preglabellar field very narrow, almost flat, anterior border furrow broad, anterior border convex, 3 times width of preglabellar field; fixigenae horizontal, slightly convex, palpebral area more than 0.3 of glabellar width, narrow diagonal eye ridge, palpebral lobes medium-size, opposite center of glabella, posterior area narrow (exsag), triangular, 0.66 length (tr) of occipital ring with broad deep posterior furrow shallowing distally; librigenae subquadrate, convex medium-wide ocular platform, broad shallow lateral furrow, convex lateral border, short blunt genal spine. Pygidium fragmentary—axis tapered 0.8 of length to rounded end, three pleurae separated by broad shallow interpleural grooves on gently sloping pleural fields, border furrow faint, border of medium width, slightly concave, with median inbend. Inner surface punctate, outer surface not known.

*Remarks.*—This species is represented by 3 cranidia, 3 fragmentary pygidia and a librigena from one locality. It can be easily distinguished from all the described species of *Coosella* by the extreme narrowness of the preglabellar field, and the wider fixigenae. The peeled holotype, the best preserved specimen, shows some similarity to *Coosella beltensis* Lochman from Montana, but the anterior border is definitely not as wide.

*Horizon and Locality.*—SM2.

*Types.*—holotype, cranidium, U.S.N.M. 137992, paratypes, cranidia, U.S.N.M. 137993a, librigena, U.S.N.M. 137993c,d, pygidia, U.S.N.M. 137993b.

SYSPACHEILUS Resser, 1938

*Supplementary description.*—In the cranidium the position of the anterior border is variable.

Librigenae narrow with rectangular, convex ocular platform, well-defined lateral furrow and medium-wide, convex lateral border with a short pointed or blunt-ended genal spine.

Pygidium transverse, axis convex, wide, sides tapered only very slightly to broad end with median indentation on interior, continuing in a low wide post-axial ridge to margin, dorsal furrow at sides only, 3 axial rings and terminal, 3-4 pleurae, interpleural grooves shallow, pleural and border furrows faint to obsolete, border narrow to medium-width, downsloping to flat, posterior margin with a vertical median upbend. Outer surface thickly covered with small granules, with 4 to 5 narrow ridges paralleling the margin on the lateral and anterior borders of the cephalon.

*Remarks.*—The authors now confidentally claim that the correct pygidium has been associated with the cranidium of *Syspacheilus*, as well as the librigena. *Syspacheilus* ranges through more than 100 feet of the Sheep Mountain section, represented by numerous specimens of two closely related species; and the higher species, *S. dunoirensis*, is also abundant at two localities in the Clear Creek section. The association of pygidium with cranidium occurs at all localities. Resser (1938) and Lochman (1950) had assigned pygidia tentatively to the genus, and in 1954 Palmer assigned a *Coosella* pygidium to the cranidium. Palmer admitted and his figures clearly show that the tail is indistinguishable from that of *Coosella* but Palmer (1954) argued that "pygidia of the kind illustrated here have been found associated with cranidia assigned to *Syspacheilus* at horizons stratigraphically below the lowest known range of *Coosella* in central Texas. Actually *Syspacheilus camurus* and *Coosella* do occur in the same faunules in several regions of the United States, and since many of the collections consist of transported disarticulated parts of the exoskeleton, the correct association of pygidium and cranidium may depend upon the fortuitous discovery of a region in which the genus lived for a considerable length of time as a dominant member of the faunules, as was the case in the Sheep Mountain area.

The associated pygidium indicates that *Syspacheilus* is the most primitive of the Coosellidae genera as it approaches the basic ptychoparid pygidium in shape, but shows the Coosellid trends in the low short post-axial ridge, and the median upbend (instead of inbend) of the posterior margin. In *S. praecedens*, the earlier species, the upbend is only beginning to appear and from the dorsal surface the posterior border

appears smoothly curved. In *S. dunoirensis* the upbend is very pronounced, and in the highest horizons the widening of the border of the larger pygidia shows how the upbend is translated into a median posterior inbend seen from the dorsal surface (pl. 1, figs. 28,39). The sequence of specimens in the Sheep Mountain section suggests that *Syspacheilus* probably evolved from its late Middle Cambrian ancestor in this general area.

Four species are at present recognized: *S. typicalis* Resser, genotype, *S. camurus* Lochman (syn. *S. occidens* Lochman), *S. dunoirensis* (B. M. Miller) and *S. praecedens*, n. sp.

SYSPACHEILUS DUNOIRENSIS (B. M. Miller)
Pl. 26, figs. 1–25,27–36,40–48

*Blountia dunoirensis* Miller, 1936, p. 27, pl. 8, figs. 25,26.
*Syspacheilus dunoirensis* (Miller), Lochman and Duncan, 1944, p. 131–132, pl. 11, figs. 44,45.
*Syspacheilus dunoirensis* (Miller), Palmer, 1954, p. 734, pl. 78, fig. 9.
Pygidium A. DeLand and Shaw, 1956, p. 561, pl. 64, figs. 17,18.

*Supplementary description.*—In small cranidia the preglabellar field is slightly wider, and the anterior border is horizontal in position up thru 2.25 mm. in length. At 2.5 mm. in length the front part of the anterior border only slopes down, and at 3 mm. in length the entire border becomes downsloping.

Librigenae with medium-wide, convex ocular platform, broad lateral furrow, and convex, medium-wide border with minute pointed genal spine. Outer surface densely covered with fine granules, often connected to give a crinkled appearance, with 3 to 4 low ridges paralleling the margins of the lateral and anterior borders of cephalon.

Pygidium narrow-transverse, axis wide, convex, tapered only slightly to broad, almost quadrate end with median indentation, and a low, broad post-axial ridge sloping to margin, furrows shallow, 3 axial rings and terminal, pleural fields low, 0.5 width of axis, 3 pleurae, anterior pleural furrow distinct, interpleural grooves shallow, a shallow border furrow starting posterior to anterior pleural furrow, border flat to slightly convex, regularly downsloping (in old and worn specimens the border furrow appears broader and gives a slight concavity to the inner part of the border, posterior margin with a vertical median upbend. Outer surface very finely granular.

*Remarks.*—This species is represented by 150 specimens, including in OC3 four cranidia, 5 mm. to 10 mm. in length and 4 pygidia, 4 mm. to 10 mm. in length; in OC4 13 cranidia and 6 pygidia; in SM1 15 cranidia, several librigenae and 8 pygidia and in SM2 more than 20 cranidia, 15 pygidia and 8 librigenae; also 1 cranidium from SM2a. The strong convexity of the pygidium, especially the axis, causes many of the specimens to be partly broken.

In the cranidium the proportion of the preglabellar field width (sag) to the anterior border width (sag) is 1:3 ratio which is constant in the peeled specimens but tends to approach 1:2½ when the outer surface is preserved. The 1:3 ratio can be determined readily in cranidia down to 2.25 mm. in length. The lateral deepening of the anterior border furrow which gives the impression of a pair of very shallow pits is noticed only on peeled specimens.

Six pygidia, ranging in length from 1.75 mm. to 7 mm., in OC4, have a more prominent median inbend of the posterior margin and a lateral broadening of the border and concavity of the profile at this broadened part. Otherwise the pygidia are identical in structure to the commonly associated pygidia. No cranidia which could be distinguished even in minor details from the normal *S. dunoirensis* cranidium were found at this horizon however. It is quite possible that these forms represent a variety which was evolving in the direction of *Coosella*, but that as yet the cranidium had made no significant change. The form might be no more than an extreme individual variation or a sex difference. It is illustrated on plate 26 as *S. dunoirensis* var. to call attention to the form.

*Horizon and locality.*—OC3, OC4, SM1, SM2, SM2a, 40-34, 39-54, 39-50.

*Types and figured specimens.*—Cranidia, U.S.N.M. 137988a,c, pygidium, U.S.N.M. 137988e, pleisiotype, pygidium, U.S.N.M. 137988f (OC3); cranidia, U.S.N.M. 137989a-c, pygidium, U.S.N.M. 137989d

(40-34); cranidia. U.S.N.M. 137990a-e,h, pygidium U.S.N.M. 137990f, plesiotypes, pygidia, U.S.N.M. 137990g,i (OC4); plesiotypes, cranidia, U.S.N.M. 137985a-d, librigenae, U.S.N.M. 137985e,f, pygidia, U.S.N.M. 137985g,h (SM1); pygidium, U.S.N.M. 137987, plesiotypes, cranidia, U.S.N.M. 137987a-e, librigenae, U.S.N.M. 137987f,g, pygidium, U.S.N.M. 137987j (SM2) cranidium, U.S.N.M. 137986(SM2a).

SYSPACHEILUS DUNOIRENSIS var.
Pl. 26, figs. 26,37–39

*Remarks.*—The presence of six pygidia which are somewhat different from the normal form associated with the cranidium in all the other horizons in OC4 is mentioned in the discussion of the species. These pygidia show the same basic structure as the normal pygidium, but the pleural fields are slightly less than 0.5 the width of the axis and somewhat more convex; and the border becomes somewhat wider, apparently by a widening at the postero-lateral corners, and slightly concave. The broadening of the border appears to make the posterior median inbend more prominent so that the trend is toward the *Coosella* type of tail. The only other distinction noticeable is that on these pygidia the 3rd axial ring is difficult to distinguish because of the near obsolescence of the furrow behind it—but this feature may be attributed to preservation. The inner surface is covered with coarse punctae as in the normal form, but the outer surface is not preserved in any of the specimens.

*Horizon and locality.*—OC4.

*Types.*—Syntypes: U.S.N.M. 137991ax, bx.

SYSPACHEILUS PRAECEDENS, n. sp.
Pl. 27, figs. 1–18,29

Cranidium quadrate, glabella moderately convex, broad-based, tapering to rounded front, two pairs of short shallow lateral furrows, occipital ring subtriangular, convex occipital furrow deep, preglabellar field downsloping, narrow, anterior border furrow medium width, distinct, anterior border twice width (sag) of preglabellar field, convex, horizontal; fixigenae strongly convex, horizontal, palpebral lobes medium-size, opposite center of glabella, narrow distinct palpebral furrows and narrow rims, posterior area narrow (exsag), about 0.75 length (tr) of occipital ring. Librigenae narrow, rectangular, deep lateral border furrow, convex, medium-wide lateral border with short blunt-ended genal spine.

Pygidium narrow-transverse, axis convex, same width as pleural regions, tapered only slightly to broad end with median indentation, continuing into low broad postaxial ridge, 2 axial rings and terminal portion may show 3rd ring faintly, pleural regions steeply downsloping, 2 pleura separated by faint interpleural grooves, border furrow obsolete on exterior, narrow border with slight median upbend of posterior margin.

Outer surface finely granulose with narrow ridges paralleling the margin on the lateral and anterior borders of the cephalon.

*Remarks.*—This species is represented by about 15 cranidia, 5 librigenae, and 10 pygidia in SM6, one transitional cranidium in SM3, and one in 39-50 and 4 to 5 cranidia and pygidia each in SM8 and SM8a. The species both in appearance and stratigraphic position seems to be the immediate ancestor of *S. dunoirensis* (Miller), and could possibly have been the ancestor of *S. camurus* Lochman also. It differs from *S. dunoirensis* in the following: 1) the ratio of preglabellar field to anterior border is 1:2, and in adult cranidia the anterior border furrow is usually narrower; 2) the anterior border is convex and horizontal in position in adults (a position which occurs only in the small (2.25 mm.) cranidia of *S. dunoirensis*); 3) in the pygidium the 3rd axial ring is poorly defined, the border slightly narrower, and the upbend of the posterior margin slight. In both species the downslope of the pleural regions is much steeper in the small pygidia than in the larger ones.

The cranidium of this species differs from that of *S. camurus* only in the horizontal position of the anterior border.

Two of the cranidia show variations in the direction of *S. dunoirensis.* A cranidium from SM3 (pl. 27, fig. 6) has the anterior border in horizontal position but the ratio is 1:2.5 and the anterior border furrow is

not very wide. Another cranidium from 39-50 (pl. 27, fig. 29) has a ratio of 1:2, a wider anterior border furrow and the anterior border slightly downsloping. Both specimens are believed to indicate some of the possible variations in the populations of *S. praecedens* which gradually evolved into the later *S. dunoirensis*, and are included in the older species.

*Horizon and locality.*—SM3, SM6, SM8, SM8a, 38-4, 39-50.

*Types.*—holotype, cranidium, U.S.N.M. 137994 (SM6); paratypes, cranidia, U.S.N.M. 137995b,c,d,f,g, pygidia, U.S.N.M. 137995k,m, librigenae, U.S.N.M. 137995h,i, (SM6); paratypes, pygidia, U.S.N.M. 137996a,b (SM8); paratypes, pygidium, U.S.N.M. 137997a, librigenae, U.S.N.M. 137997b (SM8a); paratype, cranidium, U.S.N.M. 137998 (SM3); paratype, cranidium, U.S.N.M. 138003 (39-50).

SYSPACHEILUS PRAECEDENS var. ELONGATUS, n. var.
Pl. 27, figs. 19–28,30

At the three horizons there occur a small number of cranidia in the *Syspacheilus praecedens* population which differ from the more common type in that the glabella seems to be more elongate. Some meraspid cranidia are placed here and some with the normal form. It should be noted that apparently in all small cranidia (meraspid and holaspid under 3 mm.) the glabella is always more elongate than in the larger holaspids of the species. On the smaller cranidia of this variety the granules also appear somewhat coarser. Ten cranidia in all are assigned to this variety. Tentatively referred to the variety are two pygidia of *S. praecedens* which differ from the normal pygidia in having the pleural regions somewhat narrower in proportion when compared to the width of the axis. One of these pygidia also shows a very minute spine at the end of the anterior pleural segment.

This group of cranidia and pygidia are here named a variety to call attention to these differences. Actually they probably represent sporadic individual variations in the large *Syspacheilus* population.

*Horizon and locality.*—SM6, SM8, SM8a.

*Types.*—Holotype, cranidium, U.S.N.M. 137999 (SM6); paratypes, cranidia, U.S.N.M. 138000a,b,c,e, pygidia, U.S.N.M. 138000n,o (SM6); paratypes, cranidium, U.S.N.M. 138001 (SM8); cranidium, U.S.N.M. 138002 (SM8a).

Family—MARJUMIIDAE
MODOCIA CENTRALIS (Whitfield)
Pl. 29, figs. 1–39

*Crepicephalus* (*Loganellus*) *centralis* Whitfield, 1877, p. 10.
*Modocia centralis* (Whitefield), Lochman and Duncan, 1944, p. 127, pl. 11, figs. 40–43 (synonymy to date).
*Modocia* cf. *M. centralis* (Whitfield), Palmer, 1954, p. 763, pl. 87, fig. 8.
*Modocia centralis* (Whitfield) Shaw, 1956, p. 141 (complete synonymy to date).
*Modocia centralis* (Whitfield) DeLand and Shaw, 1956, p. 558, pl. 64, fig. 10.

*Remarks.*—*Modocia centralis* ranges thru about 125 feet of the Sheep Mountain section, but is most prominent in the lower part of the section at horizons equivalent to the lower and middle *Cedaria* subzones. It is still represented by a few fragmentary specimens in SM1 and SM2, but apparently reached its maximum development in this region in SM6 in a middle *Cedaria* subzone assemblage.

The species is represented by modest numbers, but by all parts of the exoskeleton at almost all horizons. This occurrence as well as the long range indicates that it was a normal inhabitant of this region during the entire time. The present recorded geographic range of the species is from southwestern Montana and western Wyoming to the Black Hills. Specimens from the various horizons, and also in various stages of preservation, are figured for comparison. The type of preservation often influences the depth of the furrows, the apparent elongation of the glabella and roundness of the front of the glabella. In the cranidia there is actually very little individual variation to be observed in spite of the long stratigraphic range. The only consistent variation was noted in the cranidia of SM6. Regardless of size, some cranidia may have one row of granules on the preglabellar field, in which case the anterior border furrow is relatively wide (sag); the other group have three rows of granules (sag) on the preglabellar field and the anterior border furrow is narrower. The best preserved cranidia and librigenae show that the sur-

face ornamentation consists of a covering of small granules over the exoskeleton, on which is superimposed the larger granules which very probably bore important sense organs, opening to the exterior, and so were not surface ornamentation in the true sense. These larger granules go through to the inner surface, and frequently are arranged in radiating rows on the ocular and preglabellar fields reflecting the same pattern as the internal caecal venations.

The associated pygidium is not very abundant. The largest is 4.5 mm., slightly larger than the one figured by Palmer (1954, pl. 87, fig. 3), which Shaw (1956) later noted was to be referred to *M. centralis*. The *Modocia* pygidium is very distinctive, as the anterior three pleurae retain their identity at the lateral margin, ending either in short spines or in the larger pygidia as blunt nodes. A trace of the border can be detected through the ends of the pleurae, but the border as an entity occurs only along the posterior part. A series of four small pygidia in SM2, tentatively placed here, shows the most distinct development of the spines and with the above mentioned reduction to nodes in the larger pygidia, suggests that in the largest pygidia the border would be complete.

On the pygidium the axis is tapered on the outer surface, but ends bluntly on the interior mold; three axial rings and terminal portion; and 4 pleurae on pleural regions with interpleural grooves quite faint but pleural furrows broad and distinct. When the outer surface is well preserved a row of 4 or more coarse granules crosses each axial ring and an anterior and posterior row of granules cross each pleura.

A single hypostoma with the anterior edge broken, and a pleural fragment from a thoracic segment which shows a row of coarse granules on both the anterior and the posterior half as observed on the pleurae of the pygidium have been referred to the species and figured.

*Horizon and locality.*—OC3, SM1, SM2, SM3, SM4, SM5, SM6, SM8, SM8a, ?SM10, 39-53, 39-22 (38-4), 40-34, 38-32, 39-51.

*Figured specimens.*—cranidia, U.S.N.M. 138016a,b (OC3); thoracic segment, U.S.N.M. 138020 (40-34); librigena & pygidium, U.S.N.M. 138009a,b (SM1); pygidia, U.S.N.M. 138010b,c,d,e,f (SM2); librigena & pygidium, U.S.N.M. 138017a,b (SM5); cranidia, U.S.N.M. 138018a–d, librigenae, U.S.N.M. 138018e,f, pygidia, U.S.N.M. 138018g,h, hypostoma, U.S.N.M. 138018i (SM6); cranidia & librigenae, U.S.N.M. 138019a,b,c,d (SM8a); pygidium, U.S.N.M. 138012 (39-54); cranidia & pygidium, U.S.N.M. 138013a–e (39-22); cranidium, U.S.N.M. 138014 (38-4); cranidium, U.S.N.M. 138015 (39-51); cranidia, U.S.N.M. 138011a,b (SM3).

### TALBOTINA JEWELI Lochman
Pl. 29, figs. 44–46,51,52

*Talbotina jeweli* Lochman in Lochman and Duncan, 1944, p. 130–131, pl. 12, figs. 6–12.

*Remarks.*—This species is very poorly represented in the collections, two cranidia, 3.5 and 4 mm. in length from SM6 and one 11 mm. in length from SM5. The surfaces are partially worn but the smaller ones still show some granules. It is surmised that these specimens must have been transported fortuitously some distance, and that the local region was not the normal habitat of the species.

*Horizon and locality.*—SM6, SM5.

*Figured specimens.*—Cranidia, U.S.N.M. 138023a,b (SM6); cranidium, U.S.N.M. 138024 (SM5).

### TALBOTINA sp. cf. T. JEWELI Lochman
Pl. 29, figs. 47–50

*Remarks.*—Several pieces of thin-bedded limestone from SM3 have rather deeply weathered trilobite fragments on the weathered bedding planes. *Modocia*, *Paracedaria*, *Cedaria*, cystoid plates and four cranidia referred to *Talbotina jeweli* could be identified. The specimens are actually limestone molds on which the weathering has either deeply etched the lateral furrows or entirely obliterated them, and distorted the convexity and proportions of the preglabellar field and anterior border. The generic identification is considered probable, but the specific determination cannot be accurate with this material.

*Horizon and locality.*—SM3.

*Figured specimens.*—cranidia, U.S.N.M. 138025a–c,

SHICKSHOCKIA? OCCIDENTALIS, n. sp.
Pl. 29, figs. 40–43

Cranidium, librigenae and thorax not known.

Pygidium subtriangular, moderately convex, axis wide, convex anteriorly, sloping down posteriorly, tapered slightly to broad rounded end with a low narrow post-axial ridge extending to margin, 4 axial rings and terminal, anterior ring with a large vertical median spine, pleural fields 0.5 width of axis, downsloping, 2 pleurae, only anterior interpleural grooves distinct, faint shallow border furrow, narrow downsloping border, posterior margin bends up sharply on median line. Outer surface finely granular.

*Remarks.*—Only two trilobite genera have been described from the Dresbachian faunas of the United States and Canada which have median spines or nodes on the axial rings, *Meteoraspis spinosa* from the upper *Cedaria* subzone of Montana, and *Shickshockia cristata* Rasetti, a monotypic genus from a late *Cedaria* or very early *Crepicephalus* faunule from the western Gaspé. The single complete pygidium from Sheep Mountain is small, 1.75 mm. in length by 2.75 mm. in width, whereas Rasetti's figured pygidium is 8 mm. by 12 mm. In spite of the difference in size the two pygidia are very similar in shape and basic structure as well as in such details as the single axial spine and the median upbend of the posterior margin. The form is represented by only four pygidia, of which only the holotype is complete. It has been described as a new species, tentatively referred to *Shickshockia*, until cranidia and librigenae can be associated. The Sheep Mountain area was not the normal habitat of the species, and these few specimens may have been transported some distance.

*Horizon and locality.*—SM2.

*Types.*—holotype, pygidium, U.S.N.M. 138021, paratype, pygidium, U.S.N.M. 138022.

Family MENOMONIIDAE
BOLASPIDELLA WELLSVILLENSIS
(Lochman & Denson)
Pl. 30, figs. 1–5

*Howellaspis wellsvillensis* Lochman and Denson in Lochman and Duncan, 1944, p. 125–126, pl. 15, figs. 18–20.

*Howellaspis snowyensis* Duncan in Lochman and Duncan, 1944, p. 126–127, pl. 15, figs. 14–17.

*Bolaspidella wellsvillensis* (Lochman and Denson), Palmer, 1954, p. 741, pl. 83, figs. 11 (synonymy to date).

*Remarks.*—This species is represented by 5 fragmentary, worn cranidia. All the specimens have obviously been subjected to considerable transport and may have been reworked from a lower horizon. Two of the cranidia are still complete enough to leave no doubt about their identification, and the other specimens show transition stages of progressively greater wear which has given them deceptively different appearances:—the width (tr) of the frontal area has been narrowed by wear on the facial sutures and the anterior border has a low, flat character rather than an upturned rim.

*Horizon and locality.*—SM10.

*Figured specimens.*—cranidia, U.S.N.M. 138109a–d.

BOLASPIDELLA sp. undet.
Pl. 30, figs. 15,16

Two small broken cranidia from horizon SM3 appear to belong to *Bolaspidella* in so far as can be determined from the structure of the broken specimens. The shape of the glabella, the configuration of the frontal area and the indication that the palpebral areas of the fixigenae were upsloping and almost as wide as the glabella, and the presence of medium-sized granules over the surface all suggest the diagnostic characters of *Bolaspidella*. This form must represent a different species from *B. wellsvillensis* (Lochman & Denson) which occurs 55 feet lower in the section. It differs from all described species in having the flat preglabellar field regularly downsloping from the front of the glabella, rather than horizontal or depressed-concave in position. These two cranidia are approximately 2.5 mm. in length.

A smaller cranidium (1.2 mm. in length) from horizon SM2 shows a similar structure and outer granular surface and is tentatively placed in this group.

*Horizon and locality.*—SM2, SM3.

*Figured specimens.*—cranidia, U.S.N.M. 138110a,b (SM3).

DENSONELLA PRAESEMELE, n. sp.
Pl. 30, figs. 6,7

Cranidium subquadrate, glabella short, broad-based, tapered to rounded front,

moderately convex, 2 to 3 pairs of very short lateral furrows, dorsal furrow distinct at sides, shallow across front of glabella, occipital furrow narrow, distinct, occipital ring broad, convex, preglabellar field narrow (sag) but wide (tr), slightly downsloping, anterior border furrow narrow, shallow, arcuate forward, anterior border narrow, tapered at each end, rising steeply up and then dropping vertically to straight margin; fixigenae strongly convex, palpebral area 0.66 of glabellar width, palpebral lobes opposite anterior third of glabella, small, crescentic, lying in horizontal position, posterior area broad (exsag), over 1.3 length (tr) of occipital ring. Librigenae elongate, subtriangular, shape as in *D. semele*, with small eye at inner angle.

Pygidium transverse, axis convex, tapered to rounded end, 3 axial rings and terminal, pleural regions same width as axis, 3 pleurae ending at margin in minute spines, interpleural grooves faint, diagonal pleural furrows, no border furrow or border. Outer surface with a row of coarse granules across axial rings and each side of pleurae.

Outer surface covered with a fine wrinkled to granular pattern with a few coarse granules on fixigenae and two rows of paired granules along the glabella.

*Remarks.*—This species is founded on a moderate number of cranidia, librigenae and a few pygidia from three horizons in the 30 feet below SM6. The specimens from the upper ten feet of this unit are referred to the variety *D. praesemele transitans*. In spite of the limited material, a definite change can be noted in the cranidia of *Densonella* at SM7 and this trend continues as low as the material of the *Cedaria* zone was collected. In all these specimens as compared to the typical *D. semele*, 1) the glabella appears proportionately shorter and broader with a rounded front; 2) the (tr) width of both the preglabellar field and the anterior border is greater due to the wider spacing of the anterior branch of the facial suture.

In the cranidia from SM7, SM8, and SM8a for which the varietal name *transitans* is proposed, the palpebral areas are steeply upsloping so that the eyes appear stalked and thus are easily broken off. In the types chosen for *D. praesemele* at the lower horizons, the palpebral areas are strongly convex and upsloping and the palpebral lobes lie in horizontal position. It should be noted that this is the position in the meraspid and earliest holaspid instars in *D. semele* also but the anterior branch of the facial suture converges as in the adult.

Apparently there is no marked change in the pygidium from *D. praesemele* to *D. semele*. The pygidia which are described for this species are actually associated in SM8 with the variety *D. praesemele transitans* and a *Densonella* pygidium has not yet been found in the smaller collections at SM10 and SM11.

This species is clearly the form represented in Texas by Palmer's specimen, a cranidium which he called *Bolaspidella* sp. (1954, pl. 83, fig. 9). The gradation demonstrated by the Sheep Mountain material of known stratigraphic position clearly indicates its relation to *Densonella* and it is considered as possibly the oldest species of that genus. At a somewhat lower horizon in Texas Palmer obtained cranidia which he called *Bolaspidella prooculis*. This species is clearly a *Bolaspidella* in the structure of the fixigenae and the frontal area but differs from the typical *Bolaspidella* in the anterior position of the palpebral lobes and the stronger convexity of the palpebral areas. It seems quite probable that this species is the monophyletic ancestor of *Densonella*, which developed from the trend which increased the slope of the palpebral areas and narrowed the width (tr) of the frontal area.

*Horizon and locality.*—SM7, SM8, SM8a, SM10, SM11.

*Types.*—holotype, cranidium, U.S.N.M. 138122, paratype, cranidium, U.S.N.M. 138123 (SM11).

### Densonella praesemele transitans, n. var.
Pl. 30, figs. 8–14

This variety is recognized for a small number of cranidia, librigenae and pygidia which are found at horizons SM7 and SM8. The cranidia are broken and do not show the posterior areas of the fixigenae, but do differ consistently in the greater width (tr) of the frontal area which is like that found in the types of *D. praesemele*. However, in these cranidia the palpebral areas are so broken as to indicate that the eyes were essentially stalked in structure. No distinctions can be found in the structure of the

librigenae and pygidium between *D. semele* and *D. praesemele transitans*.

*Horizon and locality.*—SM7, SM8, SM8a.

*Types.*—holotype, cranidium, U.S.N.M. 138119 (SM7); paratypes, cranidium, U.S.N.M. 138120b, pygidia, U.S.N.M. 138120c,d (SM8); paratypes, librigena, U.S.N.M. 138121c, cranidia, U.S.N.M. 138121a,b (SM8a).

### Densonella semele (Walcott)
Pl. 30, figs. 17–47

*Millardia semele* Walcott, 1916, p. 163–164,166, pl. 28, figs. 3,3a–c.
*Menomonia semele* (Walcott), Lochman and Duncan, 1944, p. 135, pl. 14, figs. 10–13 (synonymy to date).
*Densonella semele* (Walcott), Shaw, 1952, p. 477.

Pygidium narrow-transverse, axis moderately convex, tapered 0.66 of length with narrow rounded end, 2 axial rings and terminal, pleural regions same width as axis, convex, 2 pleurae extend to margin with falcate ends, a 3rd posterior pleura poorly defined but makes low projection on margin, interpleural grooves faint, pleural furrows distinct, no border furrow or border. Outer surface thickly covered with fine granules, with a row of coarse granules on each axial ring and on each side of the pleura.

*Remarks.—Densonella semele* appears to have been another species which was a normal and relatively abundant inhabitant of this region. The species ranges through about 95 feet of the Sheep Mountain section and appears also in horizons OC3 and OC4. This material, although furnishing only a moderate number of specimens, has added considerable to the knowledge of the genus and species. Heretofore the known cranidia have been small, a maximum of 4 mm. Several cranidia reach 5 mm. and one is over 6 mm. in length, while librigenae over 7 mm. were obtained. The much better surface preservation shows that the granules are arranged in longitudinal rows on the exoskeleton, with two rows running the length of the axis of the body, from the glabella to the axis of the pygidium. A number of small broken pygidia were recovered which because of their ornamentation and proportions are tentatively associated with *Densonella*. The poor preservation of the type material from the House Range, Utah makes many of these features hard to determine.

The exoskeleton from Utah, though crushed and thus somewhat distorted, shows a cephalon 2.25 mm. in length, 23 thoracic segments and a pygidium about 1 mm. in length. The latter is not well preserved and a supplementary description has been added from the Wyoming material because Walcott's description was very brief. These proportions for cephalon and pygidium, 2:1, are accepted as probably correct.

The pygidia which are associated here with the *Densonella* cranidia are distinguished by the diagonal course of the pleural furrows and the fact that the ends of the pleurae appear as short spines along the margin. They range in size from late meraspids, 0.75 mm. in length, up to 3.75 mm. According to the inferred ratio, the largest pygidium indicates that some cephala can reach a length of 8 mm.

SM2 has furnished the largest number of cranidia and librigenae. The cranidia range in size from 1.25 mm. to 5 mm. In the 1.25 mm. cranidium the anterior border is narrower, the anterior branch of the facial suture converges more, the palpebral lobes are prominent but the palpebral areas flatten out distally. At 1.50 mm. the palpebral areas and lobes maintain a more nearly vertical position and at 2 mm. in length the typical vertical position is assumed.

*Horizon and locality.*—OC3, OC4, SM1, SM2a, SM2, SM5, SM6, 40-34:

*Figured specimens and types.*—cranidium, U.S.N.M. 138117a, librigenae, U.S.N.M. 138117b,c (OC3); cranidium, U.S.N.M. 138118a, librigenae, U.S.N.M. 138118 (OC4); cranidium, U.S.N.M. 138112m,j,l, librigena, U.S.N.M. 138112k (SM1); cranidia, U.S.N.M. 138113a,b,c,f,e, librigenae, U.S.N.M. 138113i,h, plesiotype, pygidia, U.S.N.M. 138113g,j, (SM2); cranidia, U.S.N.M. 138114a,b, librigenae, U.S.N.M. 138114c (SM5); librigena, U.S.N.M. 138116d cranidia, U.S.N.M. 13811a,b,c, plesiotypes, pygidia, U.S.N.M. 138116f,g (SM6); cranidia, U.S.N.M. 138115a,b (40-34).

Family NORWOODIIDAE
NORWOODELLA sp. undet.
Pl. 30, figs. 54,55

*Remarks.*—A single cranidium (2.75 mm. in length) and a single pygidium (0.75 mm.) from one horizon have been tentatively referred to *Norwoodella*, although assignment is quite uncertain because of the loss of the posterior areas of the fixigenae. Both cranidium and pygidium differ in details from all described species of *Norwoodella*. In the cranidium the anterior branch of the facial suture runs in quite close to the dorsal furrow, but the palpebral lobes appear longer than normal and the anterior border is horizontal in position. In the pygidium 5 axial rings and a minute terminal portion can be distinguished on the axis, and 4 pleurae with pleural furrows extend to the margins as there is no trace of either border furrow or border.

*Horizon and locality.*—OC4.

*Figured specimens.*—cranidium, U.S.N.M 138134a; pygidium, U.S.N.M. 138134b.

Family TRICREPICEPHALIDAE
METEORASPIS BOULDERENSIS DeLand
Pl. 28, figs. 20–29

*Meteoraspis boulderensis* DeLand in DeLand and Shaw, 1956, p. 557–558, pl. 63, fig. 18; pl. 64, figs. 4–6.

*Supplementary description.*—Associated librigena elongate, rectangular, convex ocular platform, deep lateral furrow, broad convex lateral border with stout genal spine.

Hypostoma narrow-elongate, anterior wings broken, central lobe strongly convex, ovoid, with deep curved furrow posteriorly and broad shallow furrow along anterior half, posterior lobe crescentic, bounded by a deep narrow posterior furrow, border narrow, rim-like, along lateral and posterior margins.

*Remarks.*—This species is represented by fifteen cranidia and an associated hypostoma and librigena from OC4 and a single broken cranidium (now 3.75 mm. in length) from SM2. No pygidia referable to *Meteoraspis* were found.

In the smaller holaspid cranidia in this material the preglabellar field appears slightly wider in proportion to the anterior border than in DeLand's holotype, but the width decreases until in cranidia 12 mm. in length (the same as the holotype) the proportion is the same and also the convexity. The three pairs of faint lateral furrows show somewhat better on the Sheep Mountain material. The holotype is slightly distorted, and consequently is identical in appearance to a somewhat distorted cranidium 9 mm. in length from this material (pl. 28, fig. 29).

The species is very similar to *M. keeganensis* Duncan from Montana as noted by DeLand and also to *M. borealis* Lochman from Newfoundland and Montana. The latter species has a very similar broad glabella but the fixigenae are narrower. The proportions and profile of the frontal area are also very similar, but the preglabellar field is slightly wider in *M. boulderensis*.

*Horizon and locality.*—OC4, SM2.

*Types and figured specimens.*—Plesiotypes, cranidia, U.S.N.M. 137977a–f, librigenae, U.S.N.M. 137977i, hypostoma, U.S.N.M. 137977h (OC4); cranidium, U.S.N.M. 137978 (SM2).

METEORASPIS GLOBOSA (Miller)
Pl. 28, figs. 7–19

*Blountia globosa* B. M. Miller, 1936, p. 25,27, pl. 8, figs. 22–24.

*Supplementary description.*—Cranidium elongate, glabella ovoid, strongly convex, sides tapered to narrowly rounded front, no lateral furrows, dorsal and occipital furrows deep, occipital ring medium width, convex, with a small median node; frontal area 0.25 length of cranidium (sag), convex, horizontal anterior border slightly wider (sag) than downsloping preglabellar field, anterior border furrow with two slit-like pits; fixigenae horizontal, palpebral area about 0.3 of glabellar width, palpebral lobe medium-size, slightly anterior to center of glabella, eye ridge very faint, posterior area narrow (exsag). Librigenae quadrate, short, quadrangular ocular platform, distinct lateral border furrow and convex, medium width lateral border. Outer surface covered with medium-size scattered granules.

*Remarks.*—This species is represented in SM2 by several librigenae and over 40 small cranidia ranging from meraspids 0.76 mm. to young adults 7 mm., and one cranidium 14 mm. in length. Six cranidia and a few

librigenae were obtained from OC4. The preponderance of small specimens in SM2 is caused by good sorting at the time of deposition of the material. This feature and the complete absence of a *Meteoraspis* pygidium from any of the collections suggests that the site of deposition was not in the normal habitat of the genus.

The shape of the cranidium and the proportions of the frontal area of this species resemble those of *M. elongata* Lochman from Montana; but only *M. metra* (Walcott) from Texas has as convex a glabella. From the latter species it differs noticeably in the convexity and proportions of the frontal area.

All of Miller's specimens were fragmentary and only cranidia were known. This additional material enables a complete description of the cranidium and the associated librigenae, but pygidia are not yet known.

*M. globosa* (Miller) can be readily distinguished from the cranidia of *M. boulderensis* which occurs at the same two horizons by the globose glabella, the proportions of the frontal area and the horizontal position of the anterior border.

*Horizon and locality.*—SM2 and OC4.

*Types.*—Plesiotypes, cranidia, U.S.N.M. 137975f,g,d,e,c,b,a, librigena, U.S.N.M. 137975k (SM2); plesiotypes, cranidia, U.S.N.M. 137976h,l,i, librigena, U.S.N.M. 137976j (OC4).

METEORASPIS INTERMEDIA, n. sp.
Pl. 28, figs. 1–6

Cranidium convex, subquadrate; glabella convex, conical, no lateral furrows, dorsal furrow narrow, deep, distinct around glabella, occipital furrow broad, deep, occipital ring low and convex; preglabellar field narrow (sag), sloping down to broad shallow anterior border furrow with two distinct rounded lateral pits and a shallow, slit-like median pit, anterior border of medium width, convex, fixigenae convex, horizontal, palpebral area 0.3 of glabellar width, palpebral lobe medium-size, opposite center of glabella, posterior area narrow, 0.8 length of occipital ring. Librigenae and pygidium not known. Outer surface finely granular.

*Remarks.*—Nine cranidia, ranging from 1.75 mm. up to 21 mm. in length were obtained from the OC3 collection only. The cranidia resemble that of *M. robusta* Lochman except for the construction of the frontal area. The slopes of both the preglabellar field and the anterior border are much more gentle than normally occur in *Meteoraspis*, and the faint median pit in the anterior border furrow can be seen in all specimens. Palmer (1954) noted that such a median pit can be detected on an occasional cranidium of the other species of *Meteoraspis*, but not as commonly as on these cranidia. In these several respects this new species varies in the direction of *Tricrepicephalus*.

*Horizon and locality.*—OC3.

*Types.*—Holotype, cranidium, U.S.N.M. 137973; paratypes, cranidia, U.S.N.M. 137974.

cf. METEORASPIS sp. undet.
Pl. 28, fig. 30

*Remarks.*—A single fragmentary cranidium shows only the front part of the glabella, the preglabellar field, anterior border furrow with two large transverse slits, and a moderately convex, horizontal anterior border. In the large size of the slit-like pits, and the profile of the frontal area the specimen most nearly resembles small specimens of *Meteoraspis intermedia*, n. sp. However, the specimen occurs far below the lowest horizon of *Meteoraspis* in this section, and in a late lower *Cedaria* subzone faunule. This would be the first record of the genus this low in the *Cedaria* zone.

*Horizon and locality.*—SM8a.

*Figured specimen.*—cranidium, U.S.N.M. 137984.

Incertae Sedis
cf. LIOSTRACINA sp.
Pl. 30, figs. 49,50

Cranidium subquadrate, wider than long, glabella low, elongate, tapered to rounded front, no lateral furrows, preglabellar field convex, wider than the narrow, horizontal anterior border furrow, a shallow narrow median furrow crosses preglabellar field, anterior border furrow distinct with median inbend; fixigenae convex, horizontal, palpebral areas 0.75 of glabellar width, narrow arcuate eye ridge, palpebral lobes small,

slightly anterior to glabellar center, posterior areas unknown. Librigenae and pygidium unknown.

Outer surface with medium-sized granules.

*Remarks.*—Three small (1 mm. in length) fragmentary cranidia from two horizons separated by about 50 feet of section from which fossils were not obtained, show a longitudinal median furrow on the preglabellar field. Such a feature is quite unknown on the trilobite genera (agnostids excepted) of the Dresbachian assemblages and otherwise in the Upper Cambrian is reported only in *Liostracinoides* Raymond from the lower Gorge formation. *Liostracina*, to which the forms are tentatively referred, occurs in the Kushan assemblages of eastern Asia. These faunas appear to be about the same age as the North American *Cedaria* zone assemblages. These specimens at 1 mm. in length cannot be positively identified, nor can they be described as new, since they may represent meraspid cranidia on which the median preglabellar furrow is an immature feature retained from an ancestral genus. And in the holaspid cranidium the furrow might be transformed into only a deep median inbend of the anterior border furrow, such as is found in *Paracedaria*, which is an abundant genus through much of the Sheep Mountain section.

*Horizon and locality.*—SM2, SM3.

*Figured specimens.*—cranidium, U.S.N.M. 138125 (SM2); cranidium, U.S.N.M. 138124 (SM3).

### Genus and Species Undet. 4
### Pl. 30, figs. 60,61

Three fragmentary librigenae from horizon SM6 and two from horizon SM5 cannot at present be associated with a described genus or species. The specimens all show an unusual inbend of the lateral margin at the base of an apparently short genal spine. The outer surface of the ocular field and the inner half of the lateral border is covered thickly with medium-sized granules while the outer half of the lateral border is crossed by 3 to 4 narrow imbricating ridges roughly parallel to the lateral margin.

*Horizon and locality.*—SM5, SM6.

*Figured specimens.*—librigena, U.S.N.M. 138127 (SM5); librigena, U.S.N.M. 138126 (SM6).

### Genus and Species Undet. 5
### Pl. 30, figs. 56–58

Three late meraspid pygidia ranging in length from 0.6 mm. to 0.75 mm. were obtained from horizon SM2. They show 5 axial rings and a minute terminal portion on the long tapered axis and about 5 pleurae with interpleural grooves and faint pleural furrows. The two anterior axial rings have median nodes or short spines. Horizon SM2 is characterized by an abundance of small forms, including many immature specimens, which has been achieved by wave sorting. Adult pygidia referred to *Shickshockia* do occur in this horizon only, but these pygidia may actually belong to a genus which does not have axial spines on the adult pygidium or to a genus which has been found in the material.

*Horizon and locality.*—SM2.

*Figured specimens.*—pygidia, U.S.N.M. 138128a–c.

### Genus and Species Undet. 6
### Pl. 30, fig. 59

A small well preserved pygidium from horizon SM10 resembles the pygidium of *Syspacheilus* in basic structure but the axis is proportionately slightly longer and tapered to a narrow rounded end. The rows of granules across the axial rings and the pleurae are well preserved and the interpleural grooves and pleural furrows more distinct than in the pygidia associated with *Syspacheilus* in the higher horizons. *Syspacheilus praecedens* is present in SM8a about 25 feet above SM10, but no cranidia of *Syspacheilus* have been obtained from the lower horizon. It may well be that this specimen represents a still earlier species of *Syspacheilus*, but positive identification cannot be made without more material.

*Horizon and locality.*—SM10.

*Figured specimen.*—pygidium, U.S.N.M. 138129.

### Genus and Species Undet. 7
### Pl. 30, fig. 51

A worn limestone mold of a small cranidium was obtained from horizon 38-4. The specimen cannot be assigned with certainty

to any known species in the material and the authors do not wish to describe it as a new form because of the poor single specimen. The smooth profile of the cranidium may be caused in large part by the worn condition of the specimen

*Horizon and locality.*—38-4.

*Figured specimen.*—cranidium, U.S.N.M. 138130.

Genus and Species Undet. 8
Pl. 30, fig. 48

A meraspid cranidium 0.625 mm. in length which is well preserved was found in horizon SM10, but cannot be associated with any adults at this time because of the small size of the collection. It is figured for future reference as it is a very distinctive specimen and should be easily placed when more material is available.

*Horizon and locality.*—SM10.

*Figured specimen.*—cranidium, U.S.N.M. 138131.

Genus and Species Undet. 9
Pl. 30, fig. 53

A single well preserved pygidium 0.75 mm. in length occurs in the 40-34 collection. It is not similar to the pygidia associated with the species in this collection, nor does it seem to have been previously described. It is figured for future reference.

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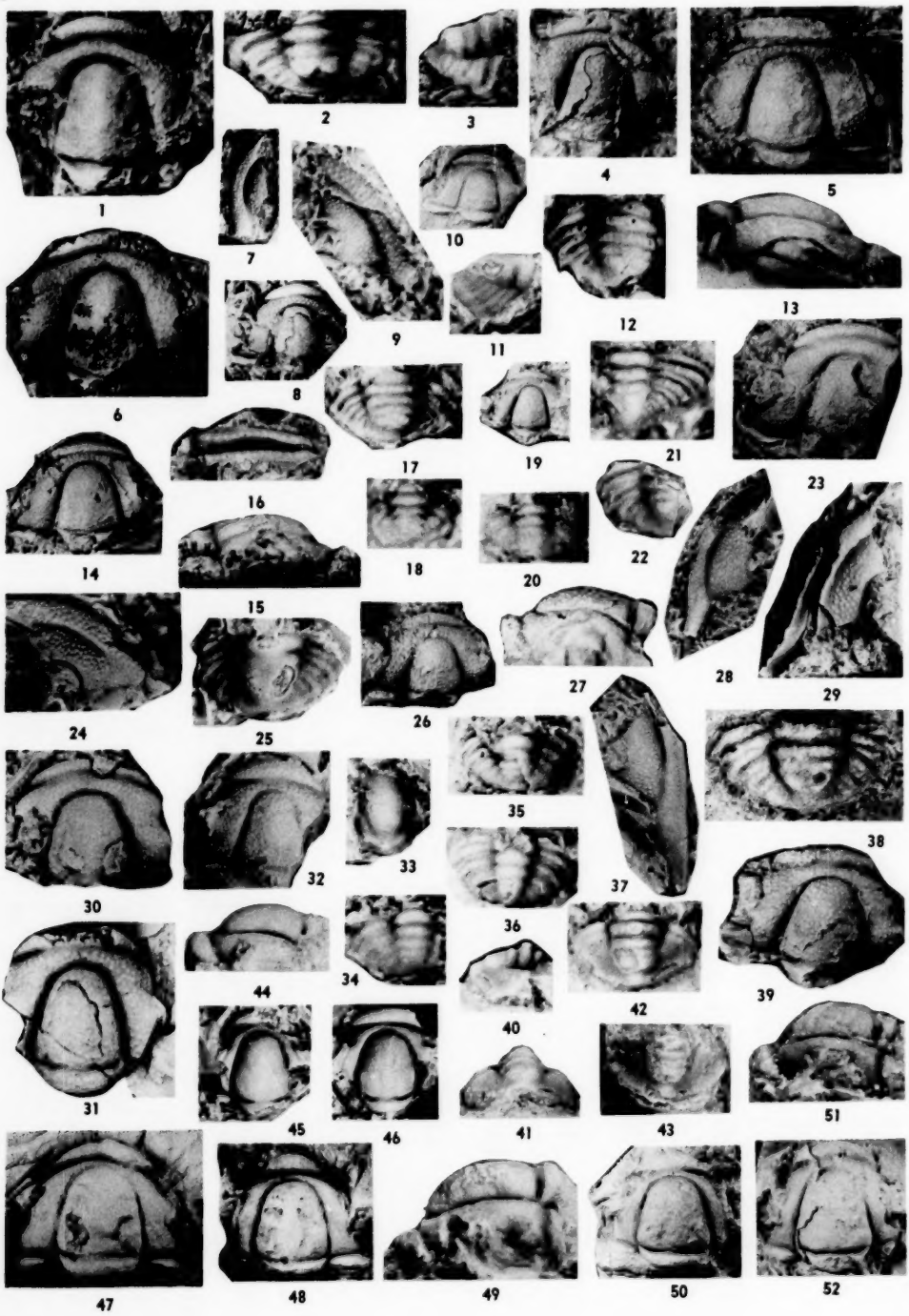
EXPLANATION OF PLATE 29

FIGS. *1–39*—*Modocia centralis* (Whitfield). Illustrating the appearance of the species through 125 feet of section—the cranidium is remarkably stable; the pygidium shows some variability. *7*, a small librigena, ×1.4, U.S.N.M. 138009a; *21*, fragment of small associated pygidium, ×9.5, U.S.N.M. 138009b, from SM1—highest horizon. *34,35,20,36*, series of meraspid pygidia, some retaining several thoracic segments, ×20, U.S.N.M. 138010b,c,d,e; *22*, a small holaspid pygidium, ×3.6, U.S.N.M. 138010f, all from SM2. *38*, deeply weathered pygidium, ×3.3, U.S.N.M. 138012, from 39–54. *16*, fragment of a thoracic segment, ×2, U.S.N.M. 138020, from 40-34. *26*, a small cranidium, ×1.5, U.S.N.M. 138016a; *27,39*, profile, dorsal of a larger cranidium, ×1.5, U.S.N.M. 138016b, from OC3. *10*, a weathered cranidium, ×1.4, U.S.N.M. 138011a; *4*, a broken cranidium, ×2, U.S.N.M. 138011b, from SM3, *5,13*, dorsal, profile of large cranidium, ×2.2, ×2.8, U.S.N.M. 138014, from 38-4; *17*, small pygidium, ×4.5; *12*, rubber mold of impression of fig. *17*, ×5.6, U.S.N.M. 138017a; *9*, associated librigena, ×4.3, U.S.N.M. 138017b, from SM5; *8*, partially peeled-cranidium showing granules on both surfaces, ×1.4, U.S.N.M. 138018a; *32,30,14*, small, medium-size, large cranidia, ×3, ×2.3, ×1.5, U.S.N.M. 138018a,c,d; *24,28*, small and large librigenae, ×3, ×1.4, U.S.N.M. 138018f,e; *33*, associated hypostoma, ×4, U.S.N.M. 138018i; *18*, meraspid pygidium, ×20, U.S.N.M. 138018g; *25,11*, dorsal, profile, a normal pygidium, ×3.2, U.S.N.M. 138018h, all from SM6, horizon of maximum abundance, 90 feet below SM1. *19,23*, a small and the largest cranidium, ×1.5, ×1.5, U.S.N.M. 138019a,b; *29*, associated librigena, ×2, U.S.N.M. 138019c; *37*, librigena with border and genal spine flatter than normal, ×1.6, U.S.N.M. 138019d, from SM8a. *1*, small fragmentary cranidium, ×3, U.S.N.M. 138013b; *6,15*, dorsal, profile of large cranidium, inner surface worn but still showing large granules, ×1.6, U.S.N.M. 138013a; *2,3*, dorsal, profile of weathered pygidium, ×1.8, U.S.N.M. 138013c, all from 39-22. *31*, weathered cranidium from 39-51, lowest horizon, ×2.3, U.S.N.M. 138015.

*40–43*—*Shickshockia? occidentalis*, n. sp. *40,41,42*, holotype, profile, rear, dorsal of small, nearly complete pygidium, ×6, U.S.N.M. 138021; *43*, paratype, a larger, poorly preserved pygidium, ×3.6, U.S.N.M. 138022, from SM2.

*44–46,51,52*—*Talbotina jeweli* Lochman. *44,46*, profile, dorsal of small cranidium with well preserved surface, ×5.5, ×4, U.S.N.M. 138023a; *45*, a second cranidium, ×4, U.S.N.M. 138023b, from SM6. *51,52*, profile, dorsal of large, poorly preserved cranidium, ×2.3, ×2, U.S.N.M. 138024, from SM5.

*47–50*—*Talbotina* cf. *jeweli* Lochman. *47*, dorsal, *48*, dorsal, *49,50*, profile, dorsal of three medium-size cranidia preserved as deeply weathered limestone molds, note etching of lateral furrows on figs. *47,48*, ×1.8, ×2, ×2.5, ×1.5, U.S.N.M. 138025a,b,c, from SM3.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*Horizon and locality.*—40-34.

*Figured specimen.*—pygidium, U.S.N.M. 138132.

Genus and Species Undet. 10
Pl. 30, fig. 52

A single fragmentary cranidium is too broken for accurate identification. The surface is well preserved and shows a Bertillon pattern of low ridges on the glabella, a reticulate pattern on the preglabellar field, and irregular transverse ridges on the flat upsloping border. The specimen suggests the genus *Coosella*, and it may be a rare second species of the genus.

*Horizon and locality.*—40-34.

*Figured specimen.*—cranidium, U.S.N.M. 138133.

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DeLand, C. R. & Shaw, A. B., 1956, Upper Cambrian trilobites from western Wyoming: Jour. Paleontology, v. 30, p. 542–562.

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Explanation of Plate 30

Figs. *1–5*—*Bolaspidella wellsvillensis* (Lochman and Denson). *1,2*, dorsal, front of best preserved cranidium, ×5, U.S.N.M. 138109a; *4*, cranidium with weathered surface, ×7, U.S.N.M. 138109b; *3,5*, two worn cranidia, ×6, ×7, U.S.N.M. 138109c,d, all from SM10.

*6,7*—*Densonella praesemele*, n. sp. *6*, holotype, larger cranidium, good surface, anterior border broken, ×4.3, U.S.N.M. 138122; *7*, paratype, a second cranidium, ×8.5, U.S.N.M. 138123, both from SM11.

*8–14*—*Densonella praesemele transitans*, n. var. *10*, holotype, a broken cranidium showing the width of the frontal area, ×7.5, U.S.N.M. 138119, from SM7. *12*, paratype, large broken cranidium, ×4, U.S.N.M. 138120b; *14,9*, paratypes, fragmentary pygidia, ×10, ×3, U.S.N.M. 138120c,d, from SM8. *13,11*, paratypes, two cranidia showing wide frontal area and apparently stalked but broken palpebral lobes, ×5, ×8.3, U.S.N.M. 138121a,b; *8*, paratype, associated librigena, ×6.4, U.S.N.M. 138121c, all from SM8a.

*15,16*—*Bolaspidella* sp. undet. Rubber mold of impression of a cranidium and a fragmentary cranidium, ×5.2, ×5.2, U.S.N.M. 138110a,b, both from SM3.

*17–48*—*Densonella semele* (Walcott). *17,20*, dorsal, profile of medium-size cranidium, ×3.5, U.S.N.M. 138115a; *18*, a large cranidium, ×3.5, U.S.N.M. 138115b, both from 40-34. *33,39,19*, a series of cranidia from 3 mm. to 6 mm. in length, ×4.4, ×5.5, ×4.4, U.S.N.M. 138116c,b,a; *32*, a librigena, ×4.4, U.S.N.M. 138116d; *23,25*, associated pygidia, ×6.3, ×6, U.S.N.M. 138116f,g, all from SM6. *21,22*, profile, dorsal of large cranidium, ×3.4, U.S.N.M. 138118a, from OC4. *26*, small broken cranidium with palpebral lobe, ×5.5, U.S.N.M. 138117a; *27,30*, associated librigenae, ×4, ×4.3, U.S.N.M. 138117b,c, all from OC3. *34*, early holaspid cranidium showing convex palpebral areas with horizontal palpebral lobes, ×12.5, U.S.N.M. 138113a; *44,45*, profile, dorsal of somewhat larger cranidium showing steeper palpebral areas, ×10, U.S.N.M. 138113b; *41,40*, average sized cranidia, ×7, ×3.5, U.S.N.M. 138113c,e; *36*, largest cranidium in horizon, ×5.2, U.S.N.M. 138113f; *35,42*, a large and a small librigenae, ×5, ×6, U.S.N.M. 138113i,h; *28*, small complete pygidium, ×10, U.S.N.M. 138113g; *24*, larger fragment of pygidium, ×7, U.S.N.M. 138113j, all from SM2. *29*, meraspid cranidium, ×12, U.S.N.M. 138112m; *37,38*, medium-sized cranidia, ×9, ×9, U.S.N.M. 138112l,j; *30*, associated librigena, ×6, U.S.N.M. 138112k, all from SM1. *43,47*, small cranidia, ×8, ×6.3, U.S.N.M. 138114a,b; *46*, librigena, ×5.8, U.S.N.M. 138114c, from SM5.

*48*—Genus and Species Undet. 8. a meraspid cranidium, ×18, U.S.N.M. 138131, from SM10.

*49,50*—cf. *Liostracina* sp. *49*, cranidium from SM2, ×18, U.S.N.M. 138125. *50*, another small cranidium shows granules on surface, ×14, U.S.N.M. 138124, from SM3.

*51*—Genus and Species Undet. 7. A worn cranidium, ×4, U.S.N.M. 138130, from 38-4.

*52*—Genus and Species Undet. 10. A single fragmentary cranidium, ×3.7, U.S.N.M. 138133, from 40-34.

*53*—Genus and Species Undet 9. A single small well preserved pygidium, ×9, U.S.N.M. 138132, from 40-34.

*54,55*—*Norwoodella* sp. *54*, a single broken cranidium, ×9, U.S.N.M. 138134a; *55*, an associated pygidium, ×7.5, U.S.N.M. 138134b, from OC4.

*56–58*—Genus and Species Undet. 5. Three late meraspid pygidia with median spines on anterior axial rings, ×18, U.S.N.M. 138128a–c, from SM2.

*59*—Genus and Species Undet. 6. A single well preserved small pygidium with granules on outer surface, ×6, U.S.N.M. 138129, from SM10.

*60,61*—Genus and Species Undet. 4. Librigenae with unusual inbend of the lateral margin, ×2.2, U.S.N.M. 138127, from SM5; ×4, U.S.N.M. 138126, from SM6.

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# JURASSIC ALGAE FROM THE SUBSURFACE OF THE GULF COAST

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ABSTRACT—Fossil calcareous algae occur abundantly in limestone cores from the subsurface of Alabama, Arkansas, and Texas. They belong to the families Codiaceae and Dasycladaceae of the Chlorophyta (green algae). Described are *Marinella lugeoni* Pfender, *Cayeuxia americana* Johnson, n. sp., *Bouenia?* sp.?, *Acicularia jurassica* Johnson, n. sp., and *Cylindroporella texana* Johnson, n. sp.

## INTRODUCTION

FOSSIL calcareous algae are known to occur abundantly in Jurassic limestones at numerous localities in Europe, Asia, and North Africa, but, with the exception of Charophyta, they are almost unrecorded from North America. The present paper describes material received by the author from a number of sources during the past fifteen years. All the specimens were obtained from cores taken from oil company borings which penetrated subsurface Jurassic beds. Table 1 shows the localities represented and sources of the material.

Most of the specimens show well preserved material. All closely resemble known European and Asiatic species. Such widely scattered occurrences suggest an extensive distribution. Once geologists become acquainted with the appearance of fossil algae and begin to look for them, these forms probably will be found frequently.

The author is grateful to the Humble Oil and Refining Company for permission to publish this paper and to the several gentlemen who supplied the specimens and slides. The Pure Oil Company kindly permitted the publication of the data from their well.

The types and figured specimens are deposited with the U. S. Geological Survey collection of fossil algae at the Denver Federal Center.

## SYSTEMATIC DESCRIPTIONS

### CHLOROPHYTA (Green Algae)
### Family CODIACEAE
### Genus MARINELLA Pfender, 1939
### MARINELLA LUGEONI Pfender
Pl. 31, figs. 1,2

*Marinella lugeoni* Pfender, 1939, p. 3, pl. 2.

*Description.*—The plants form rounded calcareous masses. They consist of branch-

TABLE 1—LOCALITIES REPRESENTED AND SOURCES OF MATERIAL

| U.S.G.S. Locality | State | Well | Depth | Source |
|---|---|---|---|---|
| D997 | Alabama (Clarke Co.) | Humble O. and R. No. 1 Emma Williams | 14010–11 | Humble Oil and Refining Company |
| | Arkansas (Columbia Co.) | McAliston Fuel Oil Gean No. 1 | 7682 to 7697 | The late E. L. Caster of Arkansas Natural Gas Company |
| D992 D993 | Texas (Navarro Co.) | Humble O. and R. No. 1 First National Bank of Corsicana | 10065 and 10151–162 | J. S. Terry and T. C. Peters of the Shell Company |
| D994 D995 D996 | Texas (Van Zant Co.) | Pure Oil No. 8 D. Swain | 10086, 10208, 10216 | Humble Oil and Refining Company |
| | Texas (Freestone Co.) | Humble O. and R. Fred Marberry | 10724 | Humble Oil and Refining Company |

ing digitated thalli. The branches may be tightly or loosely packed. The tissue is composed of fine, tightly packed tubular filaments, without cross partitions, but with occasional constrictions. The filaments may change direction frequently and may have a slightly radial or fan shaped arrangement as seen in longitudinal section. The diameter of the filaments ranges from 6 $\mu$ to 10 $\mu$, and commonly is about 9 $\mu$. In section, the tissue appears dark with noticeable growth layers.

*Remarks.*—The Texas material appears to be identical with that originally described by Pfender from the Lias of Spain and is considered to belong to the same species. It occurs locally in sufficient abundance to be a limestone builder.

*Age.*—Upper Jurassic, Cotton Valley limestone.

*Locality.*—Humble Oil and Refining Company First National Bank of Corsicana. No. 1 Well, Navarro County, Texas, at depths from 10065 to 10151 feet. U. S. Geological Survey Paleobotanical Locality D992.

*Figured specimens.*—U. S. Geological Survey Algae Numbers a843a and a844a.

### Genus CAYEUXIA Frollo, 1938
### CAYEUXIA AMERICANA Johnson, n. sp.
Pl. 31, figs. 3–5

*Description.*—Plants develop spherical or round, flattened cushion-like masses composed of numerous branching tubular filaments. The tubes show no cross partitions. The method of branching is characteristic of the genus: the branch leaves the parent stem at a sharp angle (45° to 70° depending on the species), continues a short distance, then bends sharply and grows parallel to the parent stem.

In this species, the filaments are rather closely packed, nearly parallel. There is a vague suggestion of growth zones. Tubes of medium fine size (65 $\mu$ to 95 $\mu$) show a variation in diameter even in a short distance along the same tube.

*Remarks.*—Frollo (1938) described a species, *C. moldavica*, from the eastern Carpathian region which closely resembles this one in appearance of tissue, growth habit, and size of colony, but differs in having much smaller tubes (25 $\mu$ to 50 $\mu$).

*Age.*—Upper Jurassic.

*Locality.*—Pure Oil No. 8 Swain, Van Zant County, Texas, at depths from 10086 to 10107 and 10216 to 10278 feet. U.S.G.S. Paleobotanical Locality D994.

*Type.*—U. S. Geological Survey Algae Number a845. Also figured, a846 and a847.

### Genus BOUEINA Toula, 1883
### BOUEINA ? sp.

*Description.*—A single specimen was observed which is questionably attributed to this genus. The preservation is not good, apparently because of incomplete calcification. The central third was not calcified and shows no structure. The outer rind shows evidence of branching, tubular filaments. Their size and arrangement is that of a small, probably young, codiacean, and suggests the genus *Boueina*.

*Age.*—Jurassic, probably Upper.

*Locality.*—Pure Oil Company No. 8 Swain, Van Zant County, Texas, at depth

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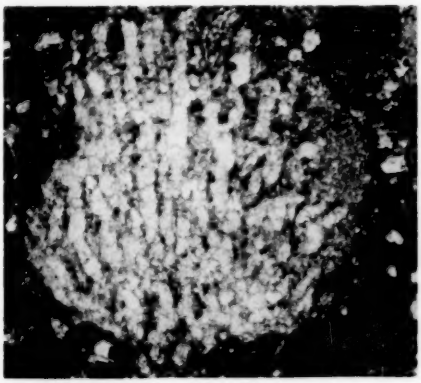
EXPLANATION OF PLATE 31

FIGS. *1–2*—*Marinella lugeoni* Pfender. Cotton Valley limestone. Humble Oil and Refining First National Bank of Corsicana No. 1; depths 10065 to 10151 feet; Navarro County, Texas. *1*, (×40) Section of a part of a plant showing tissue, character of branching and growth zones (U.S.G.S. a843a). *2*, (×100) Section of a branch showing details of tissue (U.S.G.S. a844a).

*3–5*—*Cayeuxia americana* Johnson, n. sp. Upper Jurassic. Pure Oil No. 8 Swain; depths 10086, 10208, and 10278 feet; Van Zant County, Texas. *3*, The type specimen (×40), showing the loosely packed tubes and the character of the branching (U.S.G.S. a845). *4*, A small rounded plant (×30) (U.S.G.S. a846). *5*, Part of a large flat colony (×25) (U.S.G.S. a847).

1

2



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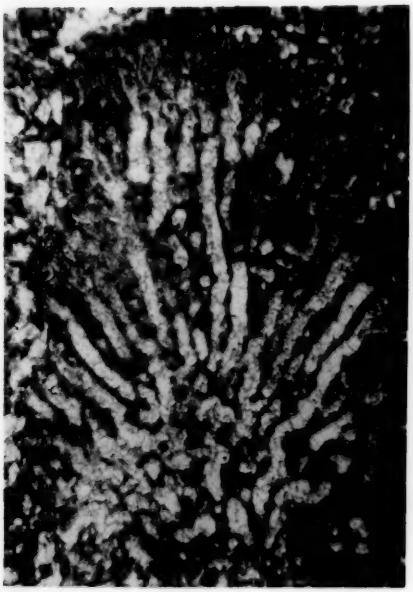

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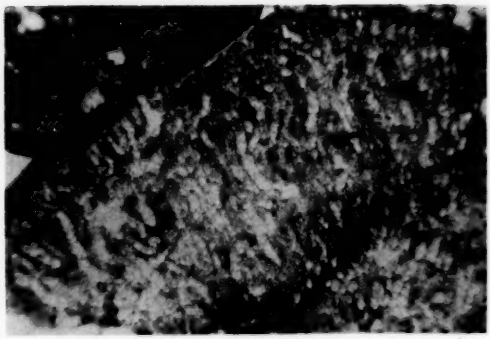

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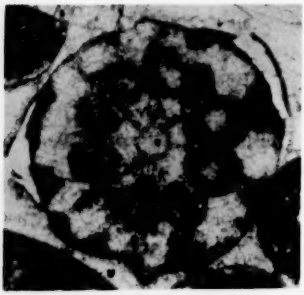

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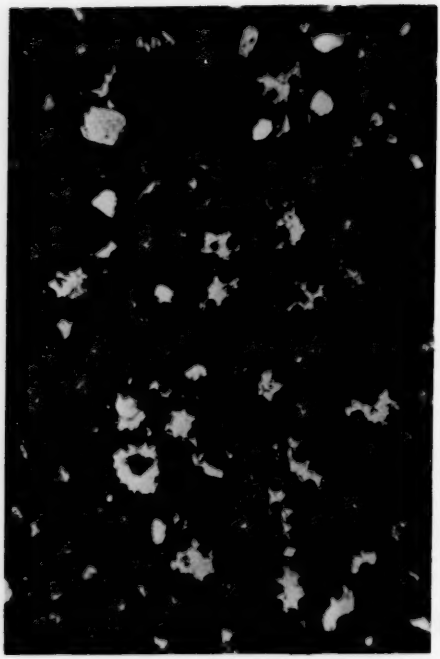

6

5

7

TABLE 2—COMPARISON OF A NUMBER OF SPECIMENS OF *Acicularia jurassica* JOHNSON, N. SP.
Dimensions in *mu* (1 mu = 0.001 mm.)

| Slide | Locality | Dimensions | No. sporangia around margin | Size of sporangia |
|---|---|---|---|---|
| Slide No. 1903 C | Clarke County, Alabama | 108×125 | 10 | 16–17 |
| HOR 1 | U.S.G.S. Locality D997 | 93×104 | 10 | 13–18 |
| | | 86× 86 | 10 | 13–16 |
| | | 95×124 | 12 | 14 |
| | | 93×114 | 10 | 13–15 |
| | | 73× 88 | 10 | 13–15 |
| | | 81×102 | 10 | 15–18 |
| Slide No. 2070 | Navarro County, Texas U.S.G.S. Locality D992 | 99×106 | 8 or 10 | 13–14 |
| | | 90× 95 | 9 – 10 | 13–15 |
| | | 89× 95 | 8 – 10 | 14–15 |

of 10216 feet. U. S. Geological Survey Paleobotanical Locality D996.

Family DASYCLADACEAE
Genus ACICULARIA D'Archiac (1843)
ACICULARIA JURASSICA Johnson, n. sp.
Pl. 32, figs. 6,7

*Description.*—The majority of the fossils consists of nearly circular discs perforated around and near the margins by nearly circular openings (sporangial cavities). Some of the larger fossils also have openings in and near the center. Some small ones have such highly incised margins as to show a star-like outline. The discs represent transverse segments of the plant.

Table 2 gives the dimensions of a number of specimens.

*Remarks.*—These are quite abundant in some of the limestones.

The only previously described Jurassic species is *A. elongata* Carozzi (1955, p. 62) from the Upper Jurassic of Switzerland. The discs of *A. elongata* are larger (140 $\mu$ to 350 $\mu$) and more elongated; have more marginal sporangia (commonly 12 to 14); and have larger sporangial cavities (diameter 30 $\mu$ to 60 $\mu$).

*Age.*—Jurassic, probably Upper.

*Locality.*—U. S. Geological Survey Paleobotanical Localities D993 and D997.

*Type.*—U. S. Geological Survey Algae Number a850. Also figured, a849.

EXPLANATION OF PLATE 32

FIGS. *1–5*—*Cylindroporella texana* Johnson, n. sp. Upper Jurassic Cotton Valley limestone, Navarro County, Texas. *1*, Cross section (×50) showing central stem, primary branches, and sporangia (type slide) (U.S.G.S. a844b). *2*, Tangential section (×50) of a fragment with sporangia, primary branches, and suggestions of the tufts of secondary branches (type slide) (U.S.G.S. a844c). *3*, Slightly oblique longitudinal section (×50) showing central stem (near top), sporangia, and some tufts of secondary branches (U.S.G.S. a843b—topotype). *4*, Tangential section (×50) cutting near outer margin; shows alternation of position of sporangia in successive whorls (type slide) (U.S.G.S. a844d). *5*, A slightly oblique vertical section (×25) containing numerous sporangia; primary branches and central stem are visible near the top (U.S.G.S. a848).

*6–7*—*Acicularia jurassica* Johnson, n. sp. Upper Jurassic. *6*, (×40) A number of worn discs from Navarro County, Texas (U.S.G.S. a849). *7*, (×40) Several typical discs from the type slide, Clarke County, Alabama (U.S.G.S. a850).

TABLE 3—COMPARATIVE DATA ON SPECIES OF *Cylindroporella*
Dimensions in mm.

| Name of species | *barnesii* | *sugdeni* | *arabica* | *texana* n. sp. |
|---|---|---|---|---|
| Length of segment | 2.8 –5.1 | 3.0+ | 1.43 | 3.29± |
| Diameter of segment | 0.38 –0.55 | 0.78 –1.14 | 0.31 –0.57 | 0.26 –0.29 |
| Diameter of central stem | 0.08 –0.14 | 0.234–0.36 | 0.052–0.230 variable | 0.038–0.040 |
| Diameter of sporangia | 0.134–0.189 | 0.26 –0.312 | 0.078–0.156 | 0.058–0.060 |
| Number of sporangia per whorl | 6 | 6 | 6 | 6 |
| Sterile branches per whorl | 6 | 6 | 6 | 6 or 8 |
| Angle of branches to stem | 90° | 90° | 90° | 90° |
| Number of secondary terminal branches | Probably 4 | 4? | 4? | 4? |
| Vertical distance between whorls | 0.17 –0.187 | 0.39 | 0.13 | 0.065–0.072 |
| Geologic age | L. Cretaceous | L. Cretaceous | U. Jurassic | U. Jurassic |

Genus CYLINDROPORELLA Johnson, 1954
CYLINDROPORELLA TEXANA
Johnson, n. sp.
Pl. 32, figs. 1–5

*Description.*—Small calcareous cylinders with rounded or acuminate ends, which formed segments of a branching plant quite similar to the Recent *Cymopolia*. Each segment consists of the calcareous mold of a narrow central stem surrounded by numerous horizontal whorls of branches. The whorls normally contain six spherical sporangia on short primary branches which alternate with long infertile primary branches. The infertile branches are slender and give rise to tufts of four short secondary branches.

Detailed dimensions and comparative data for previously described species are given in Table 3.

*Remarks.*—Three other species of this genus have been described. Each is separated from the others by dimensions and relative proportions of the internal structures.

The Texas species closely resembles the other species but is more slender and has dimensions of internal structures which are consistently smaller than the others.

*Cylindroporella texana* occurs abundantly in close association with *Marinella lugeoni* Pfender and *Acicularia jurassica* Johnson, n. sp.

*Age.*—Upper Jurassic, Cotton Valley limestone.

*Locality.*—Humble Oil and Refining Company First National Bank of Corsicana. No. 1 Well, Navarro County, Texas, at depths from 10065 to 10151 feet. U. S. Geological Survey Paleobotanical Localities D992 and D993.

*Type.*—U. S. Geological Survey Algae Number a844. Also figured, a843a and a848.

COMMENTS

The distribution of previously described material closely related to the material described here is worthy of comment. *Marinella lugeoni* was originally described from beds of Liassic age in Spain. Since then, it has been found in Czechoslovakia, Syria, Angola, and Japan. The genus *Cayeuxia*, based on a species closely related to *C. americana*, was originally described from the eastern Carpathians. It has since been obtained in Spain, Morocco, the Middle East, and Guatemala. *Boueina* is known from Morocco, the Middle East, and the eastern Mediterranean region. Only one other Jurassic species of *Acicularia* is known; it

was found in Switzerland. *Cylindroporella* was originally described from the Lower Cretaceous of Texas. It has recently been found to occur abundantly in the Upper Jurassic and Lower Cretaceous of the Arabian Peninsula and Iraq.

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# THE OPERCULUM AND MODE OF LIFE OF *HYOLITHES*

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ABSTRACT—A reexamination of *Hyolithes carinatus* Matthew from the Middle Cambrian Burgess shale has shown that the features considered by C. D. Walcott to be supports for the fins of pteropods actually appear to be outgrowths of the operculum. If the dorsal point of the operculum was hinged at the dorsal point of the aperture a push of the body outward would have swung it upward. The supports may then have served to prop up the operculum and keep it open. Because of the supports and other features of shell morphology, *Hyolithes* is interpreted as a virtually sessile, benthonic organism, the longest side of the shell being ventral.

## INTRODUCTION

IN CONNECTION with a redescription of *Selkirkia major* (Walcott) from the well-known Middle Cambrian Burgess shale of British Columbia, Walcott (1911, p. 121, pl. 19, fig. 7) illustrated, and mentioned in passing, a specimen of *Hyolithes carinatus* Matthew which preserved "curved supports for the fins of a pteropod." Although this illustration has been repeatedly reproduced in textbooks of paleontology, the Walcott material apparently has never been restudied. It is commented on in detail be-

[1] Publication authorized by the Director, U. S. Geological Survey.

### EXPLANATION OF PLATE 33

FIG. *1*—Interior of operculum of *Hyolithes* sp., ×5, U.S.N.M. No. 137906.
*2*—Exterior of operculum showing differences between the two sides, ×8, U.S.N.M. No. 137905a.
*3*—Exterior of operculum and shell in ventral view, characteristic of many of the Burgess shale specimens, ×2, U.S.N.M. No. 137905b.
*4*—Ventral view of *Hyolithes wanneri* Resser and Howell, showing shell and two supports, ×2, U.S.N.M. No. 137907.
*5*—View showing interior of ventral surface and interior of operculum, ×2, U.S.N.M. No. 137908.
*6*—Interior of operculum, ×5, U.S.N.M. No. 137905c.
*7*—Ventral view of shell and operculum, figured by Walcott, ×3, U.S.N.M. No. 57625a.
*8*—Dorsal view of shell showing support to right, ×2, U.S.N.M. No. 137909.
*9*—View showing interior of dorsal surface and operculum, ×4, U.S.N.M. No. 137905d.
*10*—Ventral view of shell and eroded operculum, U.S.N.M. No. 137910.
*11*—View showing dorsal surface with anterior part broken away and interior of operculum, ×3, U.S.N.M. No. 137905e.
*12*—View showing interior of ventral surface and interior of operculum, ×4, U.S.N.M. No. 137905f.

Specimens *2,3,* and *5–12* are *Hyolithes carinatus* Matthew. No. *1* from U.S.N.M. locality 163 (=55c); Middle Cambrian, Spence Shale member of the Ute limestone, about 50 feet above the Brigham quartzite, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles west-southwest of Liberty and 15 miles west of Montpelier, Bear Lake County, Idaho.

Nos. *2,3,6,7,9,11* and *12* from U.S.N.M. locality 35K; Middle Cambrian, Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile northeast of Burgess Pass; above Field, British Columbia, Canada.

No. *4*, from U.S.N.M. locality 22L; Kinzers shale (Olenellus zone), south of east Pittsburgh, west of Little Conestoga Creek, 1 mile west of Fruitville, Lancaster quadrangle, Pennsylvania.

No. *5*, from U.S.N.M. locality 57f; Middle Cambrian, about 2,200 feet above the Lower Cambrian, in the limestone forming bed 1 of the Stephen formation about 0.5 mile east of the great "fossil bed" on the northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

No. *8* from U.S.N.M. locality 1; Middle Cambrian shales of zones A of No. 7, of the Manuals Brook section, Manuals Brook, a small stream which flows into Conception Bay from the east, near Topsail Head, Newfoundland, Canada.

No. *10*, from U.S.N.M. locality 61g; Middle Cambrian, Stephen formation, west slope of Mount Field, about 250 feet below the summit, and 4,355 feet above the town of Field, British Columbia, Canada.

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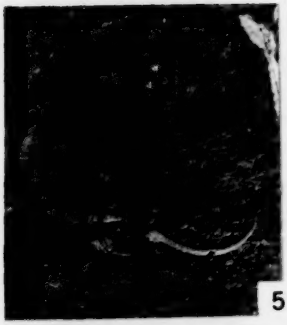
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cause the species seems to contribute significant new information about *Hyolithes*. Examination of this species led me in turn to a survey of specimens of other species and a review of the literature on *Hyolithes*.

Dr. C. J. Stubblefield, Geological Survey of Great Britain, first directed my attention to hyolithid supports and suggested (Howell and Stubblefield, 1950, p. 11,12) some of the conclusions reached herein. In connection with curatorial duties, Mr. Edwin B. Herman, U. S. National Museum, separated specimens showing supports from the remainder of the collections. Mr. Leo J. Connors, U. S. National Museum, and Mr. George Rabchevsky, U. S. Geological Survey, translated several recent articles by Russian authors. Photographs are by Nelson W. Shupe and Robert H. McKinney, U. S. Geological Survey. My colleagues. J. M. Berdan, J. T. Dutro, Jr., H. S. Ladd and A. R. Palmer read this paper and contributed many helpful suggestions.

## PRESERVATION AND IDENTITY OF MATERIAL

The Middle Cambrian Burgess shale member of the Stephen formation is renowned for the remarkable preservation of specimens some of which even show details of the soft parts. Over 200 specimens of *Hyolithes carinatus* are available from this formation; some two dozen are well enough preserved to show supports like those figured by Walcott (1911). On the other hand, there are distinct disadvantages to the Burgess shale material: (1) all specimens are compressed so that their original shape is distorted; and (2) specimens are preserved as a black carbon film on a black shale matrix, making them difficult to study and to photograph. It is worth noting that shells, opercula, and associated supports of *Hyolithes* show identical preservation, suggesting that they all originally had the same mineralogic composition.

About half of the Burgess shale specimens of *Hyolithes* lie with the longest side of the shell exposed. As the individual shale slabs in the collection do not show top and bottom criteria, it is impossible to determine if these are from the top or bottom of bedding planes. Some of the slabs contain isolated specimens; others bear many individuals close together and even lying atop one another. None of these aggregations shows any indication of orientation by currents.

*Hyolithes carinatus* was proposed by Matthew (1899, p. 42, pl. 1, figs. 5a,5b) for specimens from the Stephen shale on Mount Stephen, British Columbia. The species was mentioned briefly by Matthew (1901, p. 102) in connection with a comparison of hyolithid morphology with that of acrotretid brachiopods. Walcott (1911, p. 121) identified specimens of *Hyolithes* from the Burgess shale as Matthew's species and figured the one specimen previously noted. The same figure was repeated by Walcott (1913, p. 48, pl. 6, fig. 8; this paper—plate 33, figure 7) with the notation that it showed "the support of fin-like arms as characteristic of recent pteropods." No other literature references to the specific name are known.

Specimens in the U. S. National Museum

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EXPLANATION OF PLATE 34

FIG. *1*—Ventral view of juvenile specimen showing tip, ×3, U.S.N.M. No. 137905g.
*2*—Ventral view of incomplete specimens showing part of operculum and supports, ×2, U.S.N.M. No. 137905h.
*3*—Ventral view of operculum and shell, ×2, U.S.N.M. No. 137905i.
*4*—Ventral view of juvenile specimen showing edges of the aperture, ×4, U.S.N.M. No. 137905j.
*5*—View showing dorsal surface of shell with anterior portion broken away and interior of operculum ×4, U.S.N.M. No. 137905k.
*6*—Ventral view of best preserved specimen, ×2, U.S.N.M. No. 137905L.
*7*—View showing dorsal surface of shell with part of anterior portion broken away, interior of operculum, and one support to the left of the operculum, ×4, U.S.N.M. No. 137905m.
*8*—View showing ventral interior of shell and interior of operculum, ×4, U.S.N.M. No. 137904.
*9*—A portion of the specimen showing in figure 6, ×6.

All specimens are *Hyolithes carinatus* Matthew from U.S.N.M. locality 35k; Middle Cambrian, Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile northeast of Burgess Pass, above Field, British Columbia, Canada.

from other localities and possibly other stratigraphic horizons on Mount Stephen and nearby Mount Field were also identified by Walcott as *H. carinatus*. No attempt has been made to search for possible senior synonyms of this specific name because the literature on *Hyolithes* is so voluminous and so widely scattered. As Matthew and Walcott were both well acquainted with the literature on *Hyolithes* it is unlikely that they would have confused this species with another.

### DISCUSSION OF *HYOLITHES CARINATUS* MATTHEW

Morphologic terminology and orientation employed in this paper are shown on text-figure 1. Morphologic interpretation of this species is facilitated by separating discussion of the shell, operculum and supports.

*The shell.*—Few of the specimens examined have the earliest growth stage preserved. The few specimens that do preserve this stage (pl. 34, figs. 2,3 & 6) show a pointed tip or apex having the same angle of divergence as the more mature portion of the shell.

Measurements of the angle of divergence of half a dozen specimens selected at random fall between sixteen and eighteen degrees. Part of this slight variation might be due to the effects of compression.

The flattened condition of the material prevents preparation of thin-sections to determine if apical septa are present. None of the incomplete specimens have an apical break smoothly curved as though following a septum. There is no evidence in this species of a larval shell with a narrower angle of divergence as was reported by Matthew for some other species of the genus.

As is characteristic of *Hyolithes*, two of the sides are shorter than the third. The anterior end of the longest side farthest from the tip or apex (the shelf) is smoothly curved and is nearly semicircular. Closely spaced, fine growth lines on this surface are all convex toward the aperture. The amount of curvature of the growth lines decreases slightly toward the apex. Commonly, no other features can be seen on this surface, but a few specimens show a central slight bulging of the surface in spite of the extreme compression.

The two shorter sides join along a line which forms an axis of bilateral symmetry. In spite of compression, this line of juncture stands upward strongly suggesting that a central partition or septum, which would have resisted flattening, is in the interior. On some specimens two other lines parallel this mid-line. The most reasonable explanation for these lines seems to be that they mark the edges of a narrow central septum. A central septum has been reported from other species of the genus, and A. R. Palmer, U. S. Geological Survey, has shown me small silicified specimens, from two localities in the Cambrian of Arizona and Nevada, which have a central septum.

Growth lines on the two shorter sides are obscure. From the midline of juncture they diverge toward the aperture. On one specimen they appear to be inclined downward at nearly a forty-five degree angle to the central line; on a second, they are more strongly inclined anteriorly. Although the growth lines may be straight as a reflection of the straight margins of the aperture, one specimen has the growth lines gently convex where they are preserved on the side midway between the apex and shelf. The apertural area is almost uniformly poorly preserved. One specimen (pl. 34, fig. 4) indicates that the two edges of the apertural margin join to form about an eighty degree angle.

*The operculum.*—Many isolated opercula are scattered over the shale surfaces. A few opercula appear to be uncrushed; these are inclined at an angle to the bedding or preserved in slightly coarser matrix than is characteristic of the Burgess shale; the description is based on these specimens. The opercula appear to be less than one mm. thick.

The operculum is bilaterally symmetrical and subtriangular in outline. Two of the sides diverge at an angle near ninety degrees. The third side is rounded, its edges being the arc of a circle with a fairly large radius of curvature. This suggests that the corresponding surface of the shell was curved but because of the flattening of the shells this basal curvature cannot be proved. The exterior of the operculum is slightly convex, the highest point above the general surface being just below the juncture of the two straight sides. Several specimens (pl.

33, fig. 2) show traces of growth lines concentric around the highest point. No other exterior ornament was observed.

The two shorter sides of the operculum diverge uniformly for about three-fourths of their length from below their point of juncture almost to the third curved edge. The two edges commonly are straight, but a few specimens are irregular and differ on the two sides of the operculum (pl. 33, figs. 2,3, and 6) suggesting that the edges have been broken. These straight edges abruptly turn outward at nearly a right angle and then, after a short distance, curve inward and downward forming the third rounded edge of the operculum. When viewed from the exterior, the two sides of the operculum appear to be indented or cut away (pl. 33, fig. 1). Holm (1893, p. 73) commented on this angular indentation ("vinklight hak") shown on some opercula. Other careful drawings or photographic illustrations of opercula by various authors indicate that these indentations are a characteristic feature of lower and middle Paleozoic hyolithid opercula.

The opercula most closely associated with shells lie on and partially cover the longest side of the shell so that the most rounded edge of the operculum is farthest from the apex of the shell. The few opercula that appear to be essentially undisturbed lie with the juncture of the two straight sides of the operculum at the juncture of the two shorter sides of the shell (pl. 33, figs. 7,10; pl. 34, figs. 3,6). The precise nature of this point of juncture of shell and operculum cannot be determined.

Muscle markings have not been observed on those opercula lying with the inner surface uppermost (pl. 33, figs. 1,6). One or two specimens seem to show a faint elongate raised area near each edge and paralleling the two inward protruding ridges that might have served as areas of muscle attachment.

*The supports.*—About two dozen specimens show the supports noted by Walcott. Preservation of the supports varies from good to fair. At least one of the specimens (pl. 34, figs. 6,9) is as good or better than that which Walcott figured. There has been some movement of the supports, possibly due to compaction, so that they lie at various angles to the shell. Almost half, however, have the end nearest the operculum lying at or near to a right angle to its sides, with the distal end sweeping backward and outward, generally toward the apex of the shell. The supports are interpreted as paired structures reflecting the bilateral symmetry shown by the shell and operculum. Where supports are preserved in the Burgess shale specimens, there is always as associated shell and an operculum. No associations of isolated supports and opercula were observed.

The supports vary slightly in width, from about 0.2 to 0.4 mm., the narrower ones being associated with smaller animals. They appear to narrow slightly distally. The supports vary considerably in length with no relation to the size of the associated shell; probably this is a function of preservation, the distal end appearing broken on every specimen studied. The longest support observed is about 1 cm. in length (pl. 34, fig. 6). One or two specimens show what may be growth lines along the length of the support (pl. 33, fig. 9).

All of the supports are curved, invariably being convex forward with relation to the aperture of the shell. The curve is not a simple arc of a circle; the longest specimens strongly suggest a curve of logarithmic nature.

The supports do not lie on the bedding planes, but are inclined to them. In every case, the posterior edge of the support, that is the edge closest to the apex of the shell, lies lower than the anterior edge. Some of the specimens have part of the dorsal surface stripped away so that the interior (ventral surface) of the operculum and the supports may be seen. In spite of the unusual orientation employed, for example, plate 33, figure 5, it can be seen that the supports shown on these specimens have the same inclination to the operculum.

### RELATIONSHIP OF SUPPORTS TO OPERCULUM

I interpret the morphology of the specimens as showing that the supports did not project from the interior of the shell as implied by Walcott. Rather, the evidence indicates that the supports are on the exterior of the shell and are actually part of the operculum. A physical connection between the operculum and the supports at the area

of the notch seems to be substantiated for at least two specimens (pl. 33, fig. 12; pl. 34, fig. 9). It is only fair to admit that because of the nature of the preservation the indication of attachment is not as clear as one would like. Conclusive proof of attachment would be the finding of growth lines on the surface of the operculum continuous with those on the supports of the operculum surface; none have been observed.

Supplementary evidence of the physical connection of supports and operculum is supplied from the shape of the operculum. As noted above, some opercula have the two straight edges smooth, but others have these edges ragged and irregular near the apex. A few opercula from other localities where crushing has not been as extreme as in the Burgess shale show a suggestion of additional material extending upward and outward from the surface of the operculum. Though it cannot be proved, this again seems to indicate that the supports were part of the operculum, one on each side fairly close to the apex. A few specimens, for example, plate 34, figure 3, show the broken proximal end of the support lying on the operculum. If the support projected from the aperture, presumably it would have had to lie under the operculum.

The inclination of the supports into the matrix at an angle while the opercula lie parallel to the bedding suggests there must have had an angular relationship to the plane of the operculum. Possibly the supports joined the opercular face at a high angle. If there was an angular bend between the main body of the operculum and the support, the bend would have acted as a zone of weakness. Breakage at this zone, combined with slight movement during compression of the shale, seems to explain both the comparative rarity of the supports and the random orientation of some of the broken supports around the specimens which still preserve them, for example, plate 33, figure 7.

In living mollusks the primary purpose of an operculum is to protect the animal from harm. Commonly all of the soft parts can be withdrawn within the shell and the operculum retracted tightly either against the edges of the aperture or actually up into the aperture. It seems safe to assume that the operculum of the hyolithids had a similar protective function. This protection would be lost if any of the soft parts could not be withdrawn within the shell.

The length of the supports combined with their curvature would provide a difficult problem in the mechanics of their withdrawal into the shell. It would necessitate a crowding of the soft parts to the extreme edges of the body cavity and to the apex of the shell. The presence of the central septum dividing the body cavity in two, and further reducing the room for storing and moving the supports in and out of the shell, provides still another complication to any withdrawal of supports and postulated attached soft parts into the shells.

Accordingly, Walcott's idea that these structures supported the fins of a pteropod seems to be open to an alternative interpretation. Still another line of evidence against the fin support interpretation is Howell and Stubblefield's (1950, p. 12) comment that the Walcott figure shows no trace of the "membrane or velum attached to the 'fins' . . . " such as might be expected from the excellent preservation seen in some Burgess shale specimens of arthropods. None of the additional specimens which have the supports preserved show any trace of a membrane near the supports.

The whole argument of pteropod fins and *Hyolithes* is rather curious. Walcott wrote only one sentence outlining his idea and never elaborated on the subject. This is particularly strange for in the literature on recent Pteropoda which I have examined, there is no mention of any sort of rigid internal support for the "fins."

Syssoiev (1959, p. 894) states that the features here called supports "served as supports of gills or brachia, and possibly both of these." He also indicates that a few hyolithids had indentations on each side of the aperture just above the shelf which were not covered when the operculum was closed. He suggests that the "orifice appendages" could be pulled inside the shell through these indentations. This opinion obviously is at odds with the one presented here. Syssoiev does not illustrate these features and I am unable to evaluate his idea.

### OCCURRENCE OF SUPPORTS

In the last 45 years few opercular supports have been discovered and reported. In

addition to the specimens from the Burgess shale, a specimen of *Hyolithes* cf., *H. hathewayi* Matthew has been figured from the Lower Cambrian of North Wales (Howell and Stubblefield, 1950, p. 11, pl. 2, fig. 4) which shows these supports. Stubblefield and Bulman (1927, p. 125, pl. 3, figs. 8,14) have described and illustrated *H. magnificus* Bulman from the Tremadoc, a species having the supports preserved. Syssoiev (1959, p. 893, fig. 1) shows a drawing of a specimen from the Lower Cambrian of Siberia which appears to show both supports at an angle to the operculum, apparently skewed by compaction.

Within the U. S. National Museum collections, specimens retaining the supports have been found from the Lower Cambrian Kinzers formation in Pennsylvania (pl. 33, fig. 4) and from Middle Cambrian shales at Conception Bay, Newfoundland (pl. 33, fig. 8). One or two specimens of *H. billingsi* Walcott from Middle Cambrian shales near Argenta, Big Cottonwood Canyon, Utah, may have supports, but they could be accidents of preservation. An unnamed *Hyolithes* from the Cambrian Ross Lake shale, on Popes Peak south of Stephen, British Columbia, also appears to show the supports lying near the shell, but again poor preservation casts uncertainty on this occurrence.

It is evident, even with the uncertainty connected with the last two specimens noted above, that the distribution of opercular supports is widespread in both time and space, the occurrences covering thousands of miles and nearly one-sixth of the time for which there has been an adequate fossil record and spanning one-third of the range of *Hyolithes*. It would seem within the limits of paleontologic license to suggest that these supports are a characteristic feature of hyolithid opercula. Because of the delicate nature of the supports, it is unlikely that additional collecting will rapidly add to our information about distribution of these features.

## ORIENTATION AND MODE OF LIFE OF *HYOLITHES*

During the 19th century, there was no common agreement among those who studied *Hyolithes* regarding orientation. As summarized by Holm (review in English by Matthew, 1893, p. 435) Salter, Matthew, and Walcott considered the longest side dorsal, but Hall and Billings considered it ventral. Zazvorka (1930, text-fig., p. 8) indicated the longest surface as posterior, but gave no reason for suggesting this orientation. G. Termier and H. Termier (1953, p. 1014) refered to this side as the "Côte plat" and oriented the shell with the apex downward. A similar orientation is used in several recent textbooks of paleontology. Finally, Syssoiev (1957, p. 304), considered this surface to be ventral.

Matthew (1899a, p. 104,105) suggested that *Hyolithes* was the tube of a marine worm. He based this suggestion on the "observed larval stage, the later stages of growth, and the nature of the operculum." No opinion can be given regarding the larval shell, but the uniform expansion of most specimens throughout all post-larval stages and the bilateral rather than radial symmetry of the aperture appear to be strong evidence, although not conclusive, against considering these fossils as calcareous worm tubes.

Several lines of information suggest that *Hyolithes* did not lie buried in sediment with only the aperture above the bottom as do some of the Recent phonorid worms and hemicordates. First, there would be no opportunity for the shell to be incrusted by other organisms; such incrustations are known and are commented on elsewhere. Second, there would then be no obvious use for the shelf in front of the aperture. Third, I have seen no specimens in the collections either from the Burgess shale or elsewhere that lie at or near a right angle to the bedding surface; the preponderant number lie on bedding planes. Fourth, the shell has a triangular cross-section but many of the known living burrowing animals are modified to at least pseudo-radial symmetry.

Any discussion of orientation must necessarily consider the life habits of the animal. At least three modes of life have been suggested for *Hyolithes*. Earlier workers considered it to be allied to the pteropods because of suggested similarity in shell form between this fossil and a few of the Recent Pteropoda. By inference to these highly specialized Tertiary to Recent pelagic gastropods, it was implied that *Hyolithes* had a swimming or floating habit. However, ex-

cept for the genus *Clio* and a few closely related genera, none of the Recent pteropods have shells even superficially similar in shape to that of *Hyolithes*. Excellent reasons for rejecting this supposed phyletic relationship were given by Pelseneer (1888, p. 93) which include "their triangular form, their partitions and their operculum, which in no respect resembles that of any operculate mollusc."

Another reason for rejecting a swimming habit is the thick shell and large size of some fossil specimens, in contrast to the small, thin, light shell of the pteropods. For example, *Hyolithes maximus* Barrande (1867, p. 85) is estimated to be more than 10 cm. long. Shell thickness of this animal is not clearly shown in the illustrations, but 3 mm. seems to be a minimum figure for the shell near the aperture. The hyolithid shell apparently did not develop any mechanism for retaining buoyant gas to compensate for the weight of the shell, as has been postulated for the nautiloid cephalopod shell.

From the shape, symmetry, and size of specimens, it seems logical to conclude that *Hyolithes* was a benthonic organism (Yochelson, 1957, p. 827). If this suggestion is accepted, then there are good reasons for regarding the longest side as ventral. In this orientation the shell is bilaterally symmetrical and, when viewed from above, the margins of the aperture slope forward and downward. The rounded corner of the operculum above the apex fits snugly into the upper part of the aperture. If the operculum were hinged by some sort of ligament at the postulated dorsalmost point of each, the operculum would swing inward and downward to close.

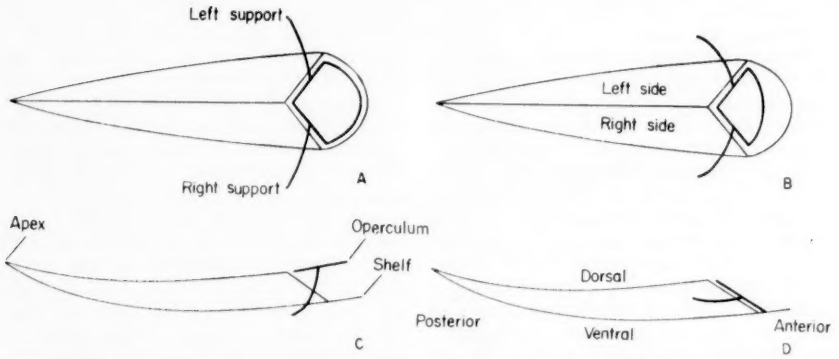
The alternative orientation would have the shell balanced on a keel-like edge where the two short sides joined and would have the edges of the aperture sloping forward and upward. This would require a continuous muscular contraction to keep the operculum closed. Finally, if the animal rested on either of the two shorter sides, one edge of the operculum would be in contact with the substrate and presumably would be immeasurably more difficult to open and close.

The additional length of this presumed ventral side seems to be explainable when considered from the aspect of functional morphology. If the shell lay on the bottom this extension (lip or shelf of authors) would prevent or at least delay sediment sifting into the open aperture. Even more important, it would provide a firm, smooth surface upon which the soft parts could move or slide forward out of the aperture.

Howell and Stubblefield (1950, p. 12) suggest that if *Hyolithes* were sedentary, "the 'fins' may have served a balancing funtion." The available information about the morphology of the opercular supports fully accords with this interpretation. The curvature seen in the cross-section of the preserved ventral surface of uncrushed specimens necessitates some sort of stabilization of the shell against possible roll by current and wave action. In some species, the ventral surface is so strongly curved that the cross-section is more properly described as elliptical or subelliptical, rather than subtriangular. Because the operculum rests on the aperture at an angle, its cross-section appears to be higher than that of the shell.

The size and shape of the supports suggests another possible or alternative function for these features. As illustrated in the Burgess shale specimens, all supports lie at an angle to the plane of the outer surface of the operculum. Assuming that the supports are part of the opercular structure and that the operculum fit snugly at the dorsal point of the aperture, then the supports would project upward when the operculum was closed. When the operculum was opened, however, the supports simultaneously would swing downward and forward because of their angular relationship to the opercular surface. At the final point of their downward motion they would be in contact with the substrate. In this position the supports would prop the operculum and keep it open.

If the operculum were hinged at the dorsal point of the aperture as postulated, a simple push outward (forward) at the lower edge of the operculum would swing it upward easily. Similarly, a slight pull would move the lower edge of the operculum inward (backward) and simultaneously free the distal end of the supports from the substrate. The force of gravity would then move the operculum downward and backward against the edges of the aperture and the




TEXT-FIG. 1—Schematic reconstruction of *Hyolithes:* A, C, dorsal and right side views with aperture open; B, D, dorsal and right side views with aperture closed.

supports would simultaneously swing backward and upward. The supports when raised would be aligned parallel to the shell but with their distal ends away from it. In this position they may have functioned as stabilizers to decrease the possibility of the shell being overturned by water currents, in the same way that an outrigger tends to stabilize a canoe. Text-figure 1 illustrates the suggested movement of the operculum.

The concept of the propping function and presumably the "balancing" function, is predicted on the assumptions that the supports served some useful purpose and that the apex of the operculum and dorsal point of aperture were articulated. Neither assumption can be proved. In spite of what appear to me to be plausible interpretations, others may prefer to consider the operculum as a freely movable plate, analogous to the operculum of living gastropods. With such an arrangement the operculum presumably would have to rest on the soft parts while the body was partially extended from the shell. If the body could only extend a short distance from the shell, the opercula would rest on the head area possibly interfering with efficient use of the sensory organs. In the scheme outlined above, the operculum would not have to rest on the body as the only attachment needed between hard and soft parts would be a few muscle strands.

One other feature of *Hyolithes* seems noteworthy. Although the Burgess shale specimens and others from shale are flattened, all specimens preserved in limestone that have been examined show both the presumed dorsal and ventral surfaces to be curved upward near the apex when seen in side view.

This curvature of the ventral surface is well shown in many of the hyolithid specimens illustrated by Barrande (1867) and by Holm (1893). In the earliest growth stages, this curve is more acute than in the later growth stages. Accordingly, the basal curve is not the arc of a circle. It appears to be part of the curve of an extremely large equiangular spiral, a curve of logarithmic nature. Although the ventral surface of shells of the Recent pteropod *Clio* show slight curvature near the apex, the curvature is downward, the reverse of the direction of curvature postulated for the hyolithids.

Most specimens of *Hyolithes* do not preserve the juvenile, most strongly curved, portion of the shell, making the angle of curvature of the ventral surface difficult to determine. Fortunately, virtually the complete curve is shown in the illustrations of *Hyolithes scalprum* Holm (1893, pl. 2, fig. 47). Using the method for determining the angle of curvature of an equiangular spiral outlined by Thompson (1948, p. 794), for this species the angle of curvature appears to be about thirteen degrees. For *H. cymbium* variety *fallax* Holm (1893, pl. 2, fig. 39) the angle appears to be about eighteen degrees. By way of comparison the angle of curvature of the right valve of the pelecypod

*Pecten ventricosus* is 52 degrees (Lison, 1949, p. 28).

Because the presumed basal surface is curved, some slight movement during life may have resulted from shifting of the center of gravity back and forth within the shell as the soft parts were expanded outward or retracted. Although the apical transverse partitions reported in many of the hyolithids lack a siphuncle and cameral deposits, they might have had a function similar to that suggested by Flower (1957, p. 834–836) for Paleozoic nautiloid cephalopods in that by their weight they served as an aid in adjusting the center of gravity of the shell (see also Syssoiev, 1959). If the center of gravity could have been shifted rapidly during life, as suggested for the cephalopods, the curvature of the ventral surface would have acted as a rocker to raise or lower the aperture and the shelf with reference to the substrate. At best, however, any postulated forward and backward rocking must have been slight. Because of the nature of the logarithmic curve it would have been much less in mature specimens than in juvenile ones. Probably deposition of transverse partitions was closely concurrent with the early growth stages where the shell was more strongly curved, and a permanent shift posteriorally of the center of gravity would be required to keep the anterior part of the shell from pressing down into the substrate.

Duncan (1957, p. 789–790) suggested that the hyolithids might be vagrant benthonic animals. She based this suggestion on the occurrence of two species of Ordovician bryozoan described earlier by Bassler as incrusting on hyolithid shells. As originally reported by Bassler, the bryozoans were said to cover all surfaces of the hyolithid shell. I have reexamined the specimens cited by Bassler and for one of them, *Leptotrypa ornata* Ulrich, there is no conclusive proof that the bryozoan colony covered all sides of the shell. In the other species, *Mesotrypa expressa* Bassler, there is no question but what the colony extends completely around the shell and has the zooecia growing on presumed ventral part of the shell differentiated from those on the other sides. However, the hyolithid shell has been dissolved and all that is known of it is the cavity now found within the colony. It is perfectly possible that this incrustation was on a large hyolithid. Because of curvature of the hyolithid shell, the apical part may very well have stood some slight distance above the sediment. The ventral part of the shell would certainly have been a slightly different microenvironment for the bryozoan than the dorsal and lateral slopes.

Syssoiev (1957, p. 306,307) has named many new genera recently and has divided the superorder Hyolithoidea into five orders. (See also Syssoiev, 1959a.) The life habit postulated herein refers only to those typical hyolithids showing a subtriangular to sub-elliptical shaped cross-section, the Hyolithida of Syssoiev. Various modes of life, including pelagic (Liashenko and Syssoiev, 1958, p. 179) have been suggested for some of the other proposed four orders of Hyolithoidea. Syssoiev (1959b) has recently published a short paper on the ecology of the Hyolithoidea elaborating on the ideas presented earlier. He distinguishes between benthonic forms which possess a shelf and pelagic forms in which the shelf is absent or only poorly developed.

To summarize, the morphology of *Hyolithes* suggests that it was virtually a sedentary benthonic organism. The basis for this suggestion is the evidence that the supports are lateral outgrowths of the operculum and the assumption that they were a feature of all hyolithid opercula. The operculum was thought to have been hinged above and, when pushed forward, it was propped open by the supports. Any extensive forward motion would have defeated the inferred propping function of these supports.

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# NOTES ON THE CLASS CONICONCHIA

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ABSTRACT—*Hyolithes* has been variously classified by different authors, most placing it somewhere within the Mollusca. Coniconchia Liashenko, 1957, was proposed as a class containing two super orders, Hyolithoidea and Tentaculoidea; the class was questionably referred to the Mollusca. There seems to be no reason to question placement of Coniconchia as mollusks and there is no theoretical objection to basing a class or any other major category on fossils rather than living specimens. It is suggested that each of the superorders eventually should be raised to class rank.

## INTRODUCTION

Most phyla recognized today are differentiated only on features of soft part anatomy. Unfortunately, anatomical detail is almost never available to the paleozoologist, who is forced to base most of his interpretations and classification on study of the skeleton and skeletal materials of fossils. In studying the skeletal remains of an extinct organism which have basic characteristics identical with the skeletal parts of an animal placed in an extant recognized phylum, it has been common practice to refer the fossil to that phylum. It is possible that two groups of phylum rank, one still living and one extinct, might be fundamentally different and still have skeletal characteristics in common but the possibility seems so remote as to be implausible. The only attempt in recent years to propose a phylum for organisms known only from their fossilized remains has been the work of Okulitch and Laubenfels (1953) with the Archaeocyatha.

The history of zoological taxonomy shows a gradual increase in the number of phyla recognized. An example that is familiar to all paleozoologists is the phylum name Molluscoidea (Muir-Wood, 1955, p. 13). This name was still mentioned in some paleontology textbooks as late as the second decade of this century, long after most zoologists had accepted a split of the Molluscoidea into two phyla, Bryozoa and Brachiopoda. With the further increase of information about the animals, the Bryozoa have been divided into two phyla (Hyman 1959, p. 275), and there are some workers who believe the Brachiopoda also should be divided into two phyla.

The history of divisions between the ranks of phylum and superfamily is essentially the same as that of the phyla. With increase in information an increasing number of major catagories have been named. However, although paleozoologists have proposed few extinct phyla, they have proposed a fairly large number of subordinate major divisions known only from fossils. Perhaps the better known examples are the subphylum Stomochorda, which includes one class and several orders based on extinct organisms (Bulman, 1955, p. v4), and the Trilobitomorpha, composed exclusively of classes and orders whose members are extinct (Størmer, 1959, p. 029). The general recognition and stability of these major categories is sufficient proof of the validity of the logic employed by their proposers. With the discovery and interpretation of additional fossils, the proposal of major categories for extinct forms is bound to continue.

The most important attribute of any class in zoology appears to be its relatively large degree of distinctness from other related classes within a phylum. Diversity, as indicated by the number of genera and species included within a class, is not a consideration. As proof of this one may see that within the Mollusca are included the Gastropoda, a class whose abundance and variety is second only to that of the insects, and the Scaphopoda, one of the more uncommon and little varied of all the classes of animals currently recognized.

In zoological literature there are literally no rules to follow regarding what should be the characteristics of a phylum, a class, or any other grouping of suprafamilial rank

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(Hyman, 1959, p. 697). Apparently one can only propose a grouping of suprafamilial rank and hope that the weight of evidence leads to its recognition. Within this operational framework, the keyword recognition appears to have only one meaningful definition, that being acceptance by a majority of the taxonomists studying that particular phylum.

To cite an example, three years ago the living monoplacophoran mollusk *Neopilina galathaea* was described and Monoplacophora was formally raised to class rank (Lemche, 1957). In this short span of time the Monoplacophora have been accepted as a group of class rank in several of the recently published textbooks. However, lack of torsion, the significant morphologic feature which is the basis for status as a separate class, had been interpreted earlier from study of fossil monoplacophorans (Knight, 1952). Examination of the Recent species has contributed much additional information about soft part anatomy but has in no way modified this interpretation of the fundamental feature of the group.

The solution employed by Knight (1952) to the problem of classification of the fossil Monoplacophora was to modify the concept of several of the molluscan classes and include the Monoplacophora and Amphineura within the revised class Gastropoda. This reduced the number of classes recognized from five to four. The discovery of a living representative of this lineage thought to have been extinct since the Devonian resulted in a return to earlier concepts of the molluscan classes and addition of another, the Monoplacophora, thereby increasing the number of recognized classes to six, or seven if one considers the Recent Aplacophora to be mollusks.

Part of Knight's decision not to recognize the Monoplacophora as a class may have been that no molluscan classes at that time had been based exclusively on fossils. This is in contrast to other phyla, for example, Coelenterata and Arthopoda, where classes known only from fossils have long been employed.

We can now see in retrospect that it would have been perfectly valid to propose the Monoplacophora as a class basing its rank on the distinctness shown by the fossils. It was not necessary to wait until the dredging of a Paleozoic relic from the depths of the sea gave dramatic proof of the correctness of the hypothesis regarding the unique features of the soft parts. Now that the pattern of five classes of mollusks has been broken, it would seem appropriate to look at other fossils to see if they too might be representatives of major categories. Hypotheses regarding the classification and soft anatomy of fossils thought to be mollusks can be proposed; their acceptance or rejection by others need not depend on the fortuitous discovery of living forms thought to be long extinct.

*Hyolithes* and its close allies apparently have never been classified to the satisfaction of most paleontologists and even though they are in a small group they may add to our understanding of basic patterns of evolution. Holm (1893) reviewed earlier ideas regarding the systematic position of *Hyolithes*. Not only was it believed to be a pteropod, a specialized pelagic gastropod, but commonly *Conularia*, now considered by many paleontologists to be a coelenterate, was classed with it. Grabau and Shimer (1910, p. 1) accepted its classification as a pteropod. Eastman-Zittel (1913, p. 571) unequivocably placed *Hyolithes* in a family of the Pteropoda within the Gastropoda. Walcott's discovery of specimens interpreted by him as showing supports for the mantle extensions characteristic of Recent pteropods appeared to give conclusive evidence as to this placement of the genus. Howell and Stubblefield (1950, p. 12) offered an alternative interpretation for the function of the supports.

Even though strong doubt was raised by Pelseneer as early as 1888, regarding placement of the hyolithids with the pteropods, most paleontologists tacitly accepted this classification. Knight (1941, p. 20) apparently was the first person in this century to unequivocably reject them from the Gastropoda stating "Hyolithidae may be mollusks, but they are more likely representatives of some phylum otherwise unknown and now wholly extinct; their resemblances to members of any living phyla are not impressive and may well be superficial."

Shimer and Shrock (1944, p. 523) placed *Hyolithes* along with several other genera in

Mollusca *Incertae Sedis*. Termier and Termier (1953, p. 1014) placed it in "Groupes d'affinités incertaines." Other proposed classifications are briefly mentioned by Liashenko and Syssoiev (1958, p. 179), who placed them as ?Mollusca.

## THE CLASS CONICONCHIA AND THE PHYLUM MOLLUSCA

Seven years ago, Liashenko (1954, p. 84) proposed the class Coniconchia, questionably referring it to the Mollusca, but did not fully diagnose it until three years later (Liashenko, 1957). The class is constituted with two superorders: the Hyolithoidea, which is divided into five orders (Syssoiev, 1957) and includes *Hyolithes* and related genera; and the Tentaculoidea (Liashenko, 1957), which is divided into three orders and includes *Tentaculites* and related genera. The class definition (Liashenko and Syssoiev, 1958, p. 180), freely translated, follows:

"Organisms with straight or slightly curved, radially or two-sided symmetrical conical shells, in size from a fraction of a millimeter to a few centimeters; with round, oval, lens-shaped, or circular-multiangulated section. The exterior of the shell is concentrically ringed, with transverse and longitudinal ribs, wrinkles and ridges; with transverse distortion; and tufted or smooth. The internal cavity in the narrow part of the shell is divided by transverse septae, without siphonal connections. The embryonic chamber is sharply conical, blunted, drop-shaped, or spherical. The aperture is perpendicular or obliquely cut. *Hyolithes* has a roofed mouth. The inner surface of the walls is smooth or annulated."

Although Liashenko shows some hesitancy about regarding the Coniconchia as mollusks, I see no need for this reservation. There is nothing about *Hyolithes* that suggests to me that it is a representative of an extinct phylum. The basic problem about its placement seems to hinge on what is meant by the term mollusk. Several definitions are available in the literature on living forms, but all define the phylum on features of soft part anatomy. Such definitions are of no direct help in the study of fossil groups.

It seems impossible at this time to define rigorously and exactly the phylum exclusively from its hard parts, unless one could find preserved in the shell material amino acids or other organic compounds that are unique to the Mollusca; this seems most unlikely. Nevertheless, the hard parts of living mollusks have certain distinctive characteristics. Because of these common features, any paleozoologist can immediately identify with a high degree of confidence, well preserved hard parts of fossil mollusks as belonging to the phylum and usually assign them to one of the extant classes

I have listed the features that I believe are common to many fossil remains placed in the Mollusca. There are obvious exceptions and nonmolluscan alternatives to every item, but any list of this sort would contain such exceptions. It seems both unnecessary and insulting to the reader to explain or justify these exceptions. Pragmatically defined, a fossil mollusk is an organism whose hard parts show most of the following items:

1. The shell is composed predominantly of calcium carbonate, and may contain both calcite and aragonite.
2. The shell is layered and not pierced by holes.
3. The shell shows prominent growth lines.
4. The shell shows a logarithmic growth pattern.
5. The shell is basically a univalve but may be modified to a bivalved condition.
6. The shell has basic bilateral symmetry, but may be modified to an asymmetrical condition.
7. The shell shows no trace of an apical attachment disk or foramen.
8. The shell may contain septa, either longitudinal or transverse.
9. The shell may have an operculum associated with it.

*Hyolithes* and its near allies fit the conditions outlined above Accordingly, I consider them to be mollusks. *Tentaculites* also seems to qualify as a mollusk.

## POSSIBLE RESTRICTION OF THE CO NICONCHIA[1]

Formal proposal of the CONICONCHIA is a significant step forward because it assigns

[1] After this manuscript was submitted for pub-

to phylum, with good reason, fossils previously considered as *incertae sedis*.

At the same time, I have two reservations regarding this class proposal. Of minor concern is the order Hyolithellida within the superorder Hyolithoidea. What little information is available on the adnate habit, composition and morphology of shell and operculum of *Hyolithellus*, type genus of the Hyolithellida, suggests that it may actually be a calcareous tube secreted by a worm-like organism. Several other genera in the superorder are based on poorly preserved specimens. Consequently, I believe that a few entities better considered with other phyla are still included in, and must eventually be moved from, the class.

My other reservation is that Liashenko and Syssoiev have been too conservative in the proposal of the Coniconchia. Although these authors have taken a basic first step, I believe that the class as proposed contains two different sorts of mollusks, each of which deserves the rank of class. Because I do not have sufficient familiarity with all the fossils in question, I hope to show the evidence suggesting this possibility without taking formal action to restrict the class Coniconchia.

There are several reasons why *Hyolithes* should be considered a representative of a distinct class. As the first point it does not show conchological features which would lead to its being assigned to any of the other classes of mollusks. It lacks the low spoon-shaped shell of the Monoplacophora, the multiple plates of the Amphineura, the siphuncle of the Cephalopoda, the two shells of the Pelecypoda, the posterior opening of the Scaphopoda, and the coiled shell of the Gastropoda.

As the second point, the shell shows an extension of the ventral surface (shelf) anterior to the aperture. The operculum develops two paired outgrowths (Yochelson, this *journal*). The shell has a trigonal cross-section. These are unique morphologic features not known in other mollusks.

The morphology of the shell suggests that the animal lived on the sea floor rather than partially buried in it. This in turn implies that the animal had a head region as is found in all living mollusks except the Scaphopoda and Pelecypoda, both of which are primarily burrowing forms.

The median longitudinal partition known in at least some of the species is another unusual feature. It suggests that the posterior part of the body may have been split in two; possibly the septum thereby provided a larger surface area for attachment of the posterior part of the body within the shell.

The mode of operation interpreted for the operculum suggests that it may have required no muscles to open it, the operculum being pushed open as the head region of the animal advanced from the aperture. This could have been accomplished by lengthening and stiffening part of the body by body fluid readjustment as is common in the foot of gastropods and pelecypods. If the operculum was propped open (Yochelson, this *journal*) only the weakest musculature would be needed to close it when the head withdrew into the shell.

One can infer that the body had undergone flexure as in the Cephalopoda; there is no indication of torsion as in the Gastropoda. It also seems, from the suggested interpretation of the opercular supports, that the soft parts could move little more than from the aperture to the edge of the anterior shelf. These speculations indicate a basic molluscan body plan with distinctive features not known in the living mollusks.

It should be noted that this account does not take into consideration the reported pelagic hyolithoids (Syssoiev, 1959, p. 893–894) considered to have air compartments in the shell. There is no information as to whether the presence of transverse septa and

lication, V. A. Syssoiev (1960, Microstructure of the *Hyolithes* shell and its systematic position, Dokl. Akad. Nauk., v. 131, no. 5, p. 1156–1158) still considered the Hyolithellida to be "genetically related with other hyolithes." More importantly, he presented new information indicating that the microstructure of hyolithid shells is of a molluscan type. He acknowledges the chronostratigraphic difference between the two superorders of the class, but recognizes the unity of the Coniconchia. Except for this point his conclusions are similar to those reached herein.

Earlier papers on *Tentaculites* and its allies have been summarized along with new information in a comprehensive work by G. P. Liashenko (1959, Coniconchia of the Devonian of the central and easter regions of the Russian platform, 220 p., 31 pls., Ministry of Geology and Natural Resources, Leningrad).

a median septum are mutually exclusive shell features.

*Tentaculites* also lacks features which are the conchological characteristics of the other presently recognized classes of mollusks. However, *Tentaculites* has several morphologic features markedly different from those of *Hyolithes*. These include the relatively large apical chamber, the overall average small size of specimens, the circular cross-section, the external annulations, and the absence of an operculum.

The dissimilarities also imply different life habits for the two groups. My interpretation is that *Tentaculites* may have been a pelagic organism in contrast to the benthonic *Hyolithes*. This is by no means a novel suggestion; the idea has been in the literature for many decades. It has also been suggested that *Tentaculites* lived in a special benthonic environment, the details of the environment not being known.

As a further consideration against the joining of these two types within the Coniconchia, the fossil record of *Tentaculites* and its close allies shows them to be abundant in beds of Silurian and Devonian age. They are unknown from younger beds and are extremely rare in older strata (Fisher and Young, 1955). This is in marked contrast to the geologic record of *Hyolithes*.

The distribution of named species of *Hyolithes* (Sinclair, 1946) indicates that it was abundant in the Cambrian, uncommon in the Ordovician, and increasingly rare in younger strata, presumably becoming extinct at the close of the Paleozoic. Another measure of stratigraphic distribution is obtained from the collections in the U. S. National Museum. Although *Hyolithes* specimens fill two cases, only about two percent of the specimens are of post-Cambrian age.

By the way of comparison for numerical abundance, all Paleozoic gastropods aggregate only about a dozen cases. Another approximation of the abundance of *Hyolithes* can be obtained from the world-wide catalogue of Cambrian described species available at the U. S. National Museum (United States Geological Survey, 1952, p. 535). Of the nearly 14,000 entries, about 9,000 apply to trilobites, 1,800 to brachiopods, 500 to archaeocyathids, 2,500 to miscellaneous groups, and 300 to *Hyolithes*. Thus, about five percent of the named Cambrian organisms have been referred to this genus.

The conclusion seems inescapable that during the Cambrian, when comparatively few mollusks as we know them today were present, the hyolithids were remarkably successful animals both in terms of abundance of individuals and taxonomic diversity. In post-Cambrian time the hyolithids were strikingly much less successful. The overall picture suggests to me that the hyolithids were relatively primitive animals unable to compete successfully with more advanced and better adapted types of mollusks.

Neither the morphology nor geologic record of the hyolithoids and the tentaculitoids is conclusive evidence at this time of differences of class rank. Nevertheless, what little is known is suggestive. It is my hope that calling attention to these suggestions will encourage further work on these and other Paleozoic fossils now classed as *incertae sedis*.

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# SILURIAN TRILOBITES FROM THE KLAMATH MOUNTAINS, CALIFORNIA

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ABSTRACT—The Gazelle formation in the Klamath Mountains is a eugeosynclinal suite of rocks from which well-preserved Silurian brachiopods and trilobites were discovered. A faunule containing the trilobites *Leonaspis* (*Acanthalomina*) *minuta* (Barrande), *Dicranopeltis* cf. *C. decipiens* (Weller), *Trochurus* sp. indet., *Scutellum* sp. indet., *Proetus* sp. indet., *Cheirurus* cf. *C. insignis* Beyrich, *Encrinurus* (*Cromus*) *beaumonti* (Barrande) is described. *Encrinurus* and *Proetus* are the only genera previously reported from the western states. *Leptaena rhomboidalis* Wilckens?, *Atrypa reticularis* Linnaeus var. *orbicularis* Sowerby?, *Atrypella scheii* (Holtedahl)?, and *Gypidula* sp. are brachiopods from this faunule.

Gazelle trilobites are very closely related to the classical Bohemian fauna and some are conspecific. In addition the brachiopod assemblage more closely resembles the Alaskan and Asian faunas than those of the Great Basin and eastern North America.

## INTRODUCTION

THIS paper describes a Silurian trilobite and brachiopod faunule from the Gazelle formation (Wells *et al.*, 1959; Churkin and Langenheim, 1960) which crops out near the eastern edge of the Klamath Mountain province, Siskiyou County, California.

The early Paleozoic sequence that underlies a wide region in the eastern Klamath Mountains is very poorly known. Metamorphic environments have obliterated fossil remains over large areas and only isolated limestone bodies have yielded datable fossils. In the summer of 1957 a detailed stratigraphic study was made of an area west of Gazelle that escaped metamorphism (Churkin and Langenheim, 1960). The trilobite faunule described in this paper was collected during this work. Discovery of well-preserved Silurian trilobites from poorly known rocks in northern California and the strong affinities of the trilobites with Bohemian species seem of sufficient interest to warrant publication.

## PREVIOUS WORK

Fossiliferous limestone along Willow Creek, southwest of Gazelle, has long been

## EXPLANATION OF PLATE 35

FIGS. *1–4*—*Leonaspis* (*Acanthalomina*) *minuta* (Barrande). *1*, Incomplete specimen, ×4, hypotype no. 34583; *2*, Almost complete specimen and detached free cheek from larger specimen, ×4, hypotype no. 34584; *3*, Large almost complete cephalon with part of the thorax attached, genal spines broken off the free cheeks, ×4, hypotype no. 34585; *4*, Small almost complete specimen, ×4, hypotype no. 34586. Gazelle formation, loc. B-5247.

*5–6*—*Dicranopeltis* cf. *D. decipiens* (Weller). *5*, Incomplete, flattened pygidium, ×4, hypotype no. 34581; *6*, Artificial replica of incomplete pygidium, ×3, hypotype no. 34582. Gazelle formation, loc. B-5247.

*7*—*Trochurus* sp. indet. Pygidium, ×4, hypotype no. 34587. Gazelle formation, loc. B-5247.

*8*—*Scutellum* sp. indet. Incomplete pygidium, ×3, hypotype no. 34588. Gazelle formation, loc. B-5247.

*9*—*Proetus* sp. indet. Almost complete specimen, glabella damaged, ×4, hypotype no. 34589. Gazelle formation, loc. B-5247.

All figured specimens are in the type collection of The Museum of Paleontology, Department of Paleontology, University of California, Berkeley, California.

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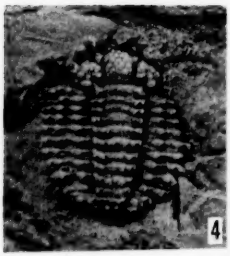
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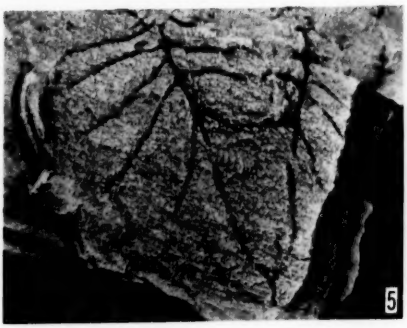
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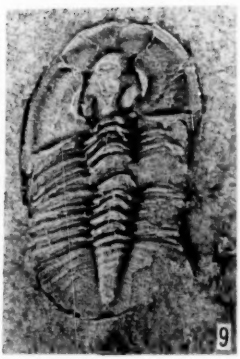
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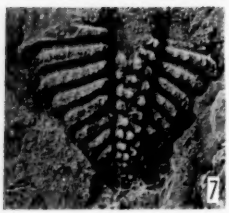
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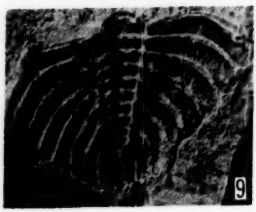
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known. In an early report (Diller, 1886) C. D. Walcott assigned a "*Lithostrotion*" collected at Willow Creek by J. S. Diller to the Carboniferous. Later, corals collected from limestone along Willow Creek southwest of Gazelle were identified as Devonian by Schuchert (Diller and Schuchert, 1894). This limestone was subsequently referred to as a northern extension of the Devonian Kennett formation of the Redding Quadrangle (Diller, 1906). Stauffer (1930) also described corals from limestone 3½ to 4 miles southwest of Gazelle as Devonian.

Merriam (1940) collected fossils from the rocks along Willow Creek, 3½ miles southwest of Gazelle, and identified them as Silurian. Furthermore, he compared his fossils with Diller's collection in the U. S. National Museum and reports that the two collections "undoubtedly represent approximately the same zones" (Merriam, 1940, p. 48). Stauffer's material also probably came from the same locality and as far as can be determined this spot is locality B-5247 (Univ. of Calif., Berkeley, Mus. of Paleon.) from which all of the material described in this paper was quarried.

ACKNOWLEDGMENTS

The writer acknowledges the helpful suggestions of C. W. Merriam of the U. S. Geological Survey. F. Prantl and A. Přibyl of the National Museum, Prague, Czechoslovakia, kindly read the manuscript, examined the original plates, and offered many valuable critical comments regarding the relationship between the Gazelle and Bohemian trilobites.

Sincere thanks are due R. L. Langenheim, Jr. for introducing the writer to the problem, assistance in the field, and for criticizing the manuscript. Research funds of the Department of Paleontology of the University of California defrayed in part the field expenses.

## STRATIGRAPHY AND LOCATION

Over 600 feet of eugeosynclinal rocks, including graywacke, shale, bedded chert, conglomerate and limestone crop out in the Gazelle area (Churkin and Langenheim, 1960). Shale and graywacke predominate, but lateral gradation from one lithologic type to another is characteristic and discontinuous lenses of bedded chert, conglomerate and limestone are widespread. These rocks, assigned to the Gazelle formation of Wells *et al.* (1959), are bounded by an overthrust mass of schist and phyllite, igneous intrusion, or alluvium in the Gazelle area and neither the top nor bottom of the formation is exposed. The youngest rocks in the outcrop area are probably those of the Payton Ranch limestone member (Churkin and Langenheim, 1960) which forms cliffs and bold outcrops on the ridges along the north and middle branches of Willow Creek. The top of the Payton Ranch limestone member, however, is either an erosion surface or a fault contact and its relation to rocks cropping out to the west is therefore indeterminate.

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EXPLANATION OF PLATE 36

FIGS. *1–3*—*Cheirurus* cf. *C. insignis* Beyrich. *1*, Incomplete cephalon and thorax, ×3, hypotype no. 34590; *2*, Pygidium and dissociated thoracic segments, ×3, hypotype no. 34591; *3*, Single isolated pleuron, ×4, hypotype no. 34592. Gazelle formation, loc. B-5247.

*4–9*—*Encrinurus* (*Cromus*) *beaumonti* (Barrande). *4*, Small almost complete specimen, cephalon without free cheeks, ×3, hypotype no. 34593; *5*, Large cephalon without free cheeks, ×4, hypotype no. 34594; *6*, Small cephalon without free cheeks, ×4, hypotype no. 34595; *7*, Almost complete pygidium of average size, ×4, hypotype no. 34596; *8*, Flattened pygidium of large size, ×4, hypotype no. 34597; *9*, External mold of complete pygidium, axis slightly damaged, ×4, hypotype no. 34598. Gazelle formation, loc. B-5247.

All figured specimens are in the type collection of The Museum of Paleontology, Department of Paleontology, University of California, Berkeley, California.

All the trilobites described in this paper were collected from brown-black shale interbeds in the thin-bedded basal portion of limestone which forms a small knob (elev. 3,600′) on the ridge trending north from the middle branch of Willow Creek in the NW¼, SW¼, NW¼, Sec. 19, T. 42N, R. 6W, China Mountain 15-minute quadrangle, Siskiyou County, California and is about 3,400′ N 45°E of BM 3333 in Sec. 24, T 42W, R. 7W, of the same quadrangle. This locality is numbered B-5247 which serves to identify the fossil collections made from this spot and stored in the Museum of Paleontology, University of California, Berkeley, California.

## COMPOSITION OF THE FAUNA

Most of the limestone within the Gazelle formation is sparsely fossiliferous, containing poorly-preserved corals, brachiopods, crinoid columnals and echinoderm fragments. Only unidentifiable fossil fragments were recovered from the graywacke, shale and bedded chert. The thin-bedded basal portions of the limestone units, however, locally contain abundant well-preserved brachiopods and trilobites.

At locality B-5247 a collection was made of well-preserved trilobite molds and associated brachiopods, coral fragments and crinoid columnals. Only a few entire trilobite impressions were found in the shale in contrast to hundreds of free cheeks, cranidia, thoracic segments and pygidia. The following fossils from this collection have been identified:

Trilobita

*Leonaspis* (*Acanthalomina*) *minuta* (Barrande)
*Dicranopeltis* sp. cf. *D. decipiens* (Weller)
*Trochurus* sp. indet.
*Scutellum* sp. indet.
*Proetus* sp. indet.
*Cheirurus* cf. *C. insignis* Beyrich
*Encrinurus* (*Cromus*) *beaumonti* (Barrande)

Brachiopoda

*Leptaena rhomboidalis* Wilckens?
*Atrypa reticularis* Linnaeus var. *orbicularis* Sowerby?
*Atrypella scheii* (Holtedahl)?
*Gypidula* sp.

## AGE AND CORRELATION

Individual elements and particularly the total impression stamp the fossil assemblage as indisputably Silurian and, probably, Middle or Upper Silurian. Closer correlation, however, must depend upon further collection in the Gazelle formation and upon more extensive and detailed descriptions of other Silurian fossil assemblages from western North America. At present these faunas are very poorly known and the isolated Gazelle assemblage must be compared directly with fossils from the standard sections of eastern North America, England, Bohemia and Siberia.

The Gazelle fossils are most strikingly similar to the classical Silurian fauna of Bohemia described by Barrande (1852). Several trilobite species from Gazelle show no significant differences from the Barrandian lectotypes and were tentatively assigned to the Bohemian species. These specific comparisons were then reviewed by Prantl and Přibyl of the National Museum of Prague, who reported that "The trilobites of Gazelle are very closely allied to the Bohemian ones. Some of them in our opinion are really conspecific" (personal communication, 1959). With their confirmation, two Bohemian species—*Encrinurus* (*Cromus*) *beaumonti* (Barrande) and *Acantholomina minuta* (Barrande) have been recognized at Gazelle.

The cosmopolitan aspect of the trilobites thus far identified in the Gazelle fauna can be more easily explained if they are considered to have been planktonic. Ruedemann (1934, p. 39) states that "there are trilobites that undoubtedly belong to the plankton . . . these include some forms of *Lichas*, especially *Acidaspis* and *Odontopleura* with large crowns of horizontal spines." These spiny forms are among those collected at Gazelle and it is thought that they were indeed planktonic and that their discarded molts sank to the sea bottom where brachiopods and corals were living. Here they were subsequently buried by argillaceous sediment.

The trilobite fauna of the Gazelle formation includes *Dicranopeltis*, *Trochurus*, *Cheirurus*, *Leonaspis* and *Scutellum*, all of which are previously unreported from the western states. Although these genera occur in eastern and middle-western North America, specific comparisons clearly indicate that the Gazelle trilobites are more

closely related to Middle and Upper Silurian trilobites of Bohemia and Asia. Furthermore, the brachiopods also seem more closely related to those of Alaska and Asia than to those of interior and eastern North America. Thus the faunal aspect of the Gazelle formation is in accord with the conclusion of C. W. Merriam (personal communication) that the Lower Paleozoic faunas of northern California have their closest affinities with Alaskan and Asian assemblages and are distinctly different from those of the Great Basin.

## SYSTEMATIC DESCRIPTIONS

### Class TRILOBITA

### Order ODONTOPLEURIDA Whittington, 1959

### Family ODONTOPLEURIDAE Burmeister, 1843

### Subfamily ODONTOPLEURINAE Burmeister, 1843

### Genus LEONASPIS Richter and Richter, 1917

### Subgenus ACANTHALOMINA Prantl and Přibyl, 1949

### LEONASPIS (ACANTHALOMINA) MINUTA (Barrande)

Pl. 35, figs. 1–4

*Acidaspis minuta* BARRANDE, 1852, pl. 37, figs. 18–22.

*Acanthalomina minuta* (Barrande), PRANTL and PŘIBYL, 1949, p. 164, pl. 1, figs. 26–29, pl. 10, figs. 6,7.

*Description.*—Small opisthoparian trilobite with carapace strikingly spinose; cephalon very convex, short, wide, semicircular in outline, genal spines bending sharply outwards and secondarily spinose; cephalon rimmed by narrow, raised border bearing small spines (less than 1 mm. long) normal to margin; glabella with well-developed, elongate, very convex, median lobe and two pairs of less prominent lateral lobes; anterior lateral lobes strongly convex, sub-ovate in outline and separated by sharp furrows from median lobe, and from large pair of basal lateral lobes by deeper posterior furrows that curve backward and inward to join occipital furrow; occipital furrow broadly rounded and deep; occipital ring simple and apparently with only single median granule; anterior branches of facial sutures branch off from ocular ridge and converge slightly to anterior margin of cephalon, forming two small subtrigonal areas between them and glabella; fixed cheeks much smaller than free cheeks, both moderately convex; eyes small and subcircular; entire surface of cephalon finely tuberculate; thorax of nine segments; thoracic axis strongly convex with rounded axial rings bearing as many as seven spinose tubercles; deep, rounded, articulating furrows separate rings; thoracic pleura slightly convex with narrow, raised ridges running out into long hollow spines; spines paralleling each other and bent posteriorly; pleural ridges apparently with three or possibly four rows of spinose tubercles; outer tubercles less prominent than inner pair and on some pleura appear to consist of two smaller tubercles branching from a single base; pygidium subtrigonal with convex axis and flattened pleural lobes; axis divided into two tuberculate rings; anterior ring with about four spinose tubercles and posterior ring with two centered tubercles on terminal end of axis; pleural lobes tuberculate; pair of faint ridges, with two tubercles on each ridge extending from dorsal furrows opposite anterior ring to margin where they continue into pair of long, principal spines; pygidial margin spinose bearing four or five pairs of slender spines with second pair from posterior end longer than others; spines at ends of thoracic pleura several times longer than pygidial spines.

Dimensions of a cephalon (hypotype no. 34584) are: length 3.5 mm., width 10 mm., length of genal spines 3 mm., width of glabella at base 2.5 mm., width of median lobe 1.3 mm., width of glabella at mid-length 4 mm.

Dimensions of a small pygidium (hypotype no. 34583) are: length 3 mm., width at anterior end 5 mm., width of axis at anterior end 1.5 mm..

Dimensions of an incomplete, small, dorsal mold (hypotype no. 34586) are: length 6.5 mm. (of which 1.5 mm. belong to cephalon, 4 mm. to thorax, and 1 mm. to pygidium), cephalon is 6 mm. wide at genal angles, thorax 6 mm. wide at anterior end, pygidium 4 mm. wide at anterior end, thoracic axis 2 mm. wide at anterior end and pygidial axis 1 mm. wide at anterior end.

This species is represented by six almost complete molds, numerous free cheeks, and pygidia.

*Hypotypes.*—Univ. Calif. Mus. Paleo. Type Coll. nos. 34583, 34584, 34585, 34586.

*Discussion.*—The Gazelle specimens agree very closely with the illustrations and descriptions given by Barrande and Prantl and only differ from the lectotype of *A. minuta* by having the main pygidial spines longer than secondary spines. Prantl and Přibyl agree that the Gazelle forms are conspecific with the type *A. minuta* in Bohemia (personal communication, 1960).

*Occurrence and range.*—Locality B-5247, Gazelle formation. "*A. minuta* is in Bohemia seemingly restricted to the Kopanina Limestones—$e\beta_1$ (Lower Ludlovian), where it occurs in the characteristic association with *Encrinurus* (*Cromus*) *beaumonti* (Barr.), *Cheirurus quenstedti* Barr., etc." (Prantl and Přibyl, 1949, p. 165).

Order LICHIDA Moore, 1959
Family LICHIDAE Hawle and Corda, 1847
Subfamily LICHINAE Hawle and Corda, 1847
Genus DICRANOPELTIS Hawle and Corda, 1847
DICRANOPELTIS sp. cf. D. DECIPIENS (Weller)
Pl. 35, figs. 5,6

*Description.*—Pygidium semielliptical in outline; axis strongly convex anteriorly and with two rounded annulations passing backward into convex bulbous portion, depressed posteriorly into wedge-shaped post-axial area; two dorsal furrows bound post-axial region and converge to posterior margin; pleural lobes slightly convex and divided into three, broad, grooved ribs, all produced marginally into short, free points; entire surface finely tuberculate.

Dimensions of a pygidium (hypotype no. 34582) are: length 7 mm., width at anterior margin 12 mm., width of axis anteriorly 3.5 mm. Collection consists of two isolated pygidia.

*Hypotypes.*—Univ. Calif. Mus. Paleo. Type Coll. nos. 34581, 34582.

*Discussion.*—The pygidia closely resemble those of *D. decipiens* Weller (Weller, 1907, p. 237, pl. 22, fig. 11) and *D. decipiens* (Weller) (Phleger, 1936, p. 612, fig. 66) but more complete specimens are needed before identity can be established.

*Occurrence and range.*—Locality B-5247, Gazelle formation. *Dicranopeltis* occurs in the Upper Ordovician of Europe and the Silurian of Europe and North America. *D. decipiens* is represented in the Niagaran of the eastern United States.

Subfamily CERATARGINAE Tripp, 1957
Genus TROCHURUS Beyrich, 1845
TROCHURUS, sp. indet.
Pl. 35, fig. 7

*Description.*—Lichadian pygidium of "Trochurus-Euarges type" (Phleger, 1936); pleural lobes divided into three sections by two pairs of ridges passing into marginal spines (1 mm. long); anterior portion of axial lobe marked by two rings continuous with these ridges; axis tapers posteriorly into short ridge (1.5 mm. long) opposite small terminal spine on margin; two broad spines (0.5 and 1.5 mm. long) occur on each side of this terminal spine making a total of nine marginal spines; axis bounded by deep dorsal furrows; entire pygidium moderately convex and covered by small tubercles.

Dimensions of the largest pygidium (hypotype no. 34587) are: length 6 mm., width at anterior end 7 mm., length of axial lobe 4.5 mm., width of axial lobe 2 mm. Collection consists of four isolated pygidia.

*Hypotype.*—Univ. Calif. Mus. Paleo. Type Coll. no. 34587.

*Discussion.*—These specimens resemble *Lichas palmata* (Barrande, 1952, pl. 28, figs. 1,9,10) but have nine large marginal spines instead of six.

*Occurrence and range.*—Locality B-5247, Gazelle formation. The genus *Trochurus* occurs in the Upper Ordovician-Middle Silurian of Europe and North America.

Order PTYCHOPARIIDA Swinnerton, 1915
Suborder ILLAENINA Jaanusson, 1959
Family THYSANOPELTIDAE Hawle and Corda, 1847
Genus SCUTELLUM Pusch, 1833
SCUTELLUM, sp. indet.
Pl. 35, fig. 8

*Description.*—Pygidium elliptical in outline; axis very short with radiating furrows extending from it across broad, flattened, pleural surfaces to margin.

Dimensions of a pygidium (hypotype no. 34588) are: length 9 mm., width at anterior margin approximately 11 mm., width of

axis anteriorly 3 mm. Collection consists of two incomplete pygidia.

*Hypotype.*—Univ. Calif. Mus. Paleo. Type Coll. no. 34588.

*Discussion.*—Such features as are preserved indicate the genus *Scutellum.*

*Occurrence and range.*—Locality B-5247, Gazelle formation. *Scutellum* occurs in Ordovician to Devonian rocks and has a cosmopolitan distribution.

Superfamily PROETACEA Salter, 1864
Family PROETIDAE Salter, 1864
Subfamily PROETINAE Salter, 1864
Genus PROETUS Steininger, 1831
PROETUS, sp. indet.
Pl. 35, fig. 9

*Description.*—Cephalon semicircular in outline and somewhat larger than pygidium; glabella tumid, moderately convex, rounded in front and extending to within 1 mm. of anterior margin; two pairs of glabellar furrows, anterior pair faint, posterior furrows deeply impressed, originating opposite eyes and extending obliquely inward and backward producing a slight convex curve near occipital furrow; occipital furrow narrow, well-defined and with pair of small, subovate, occipital lobes back of posterolateral glabellar angles; cheeks smooth, and slightly convex, sloping from dorsal furrows laterally and anteriorly to within 1 mm. of margin; raised, flattened, continuous, marginal border rims cephalon and passes posteriorly into broad genal spines lying against first six thoracic segments; posterior margin of each cheek with well-developed posterior cheek furrow running from dorsal furrow, opposite the occipital furrow, to inner side of marginal border; facial sutures opisthoparoid with divergent anterior branches; fixed cheeks narrow; free cheeks broad, apparently containing eyes of moderate size close to dorsal furrows; thorax composed of nine smooth segments; axial lobe strongly convex, bounded by deep dorsal furrows; thoracic pleura convex, inclined slightly backwards and apparently weakly furrowed; pygidium semicircular; axis strongly convex, and bordered sharply by dorsal furrows, tapering posteriorly and terminating bluntly just within marginal border; axis with about seven annulations; pleural lobes flattened bearing faint ribs continuous with axial annulations, and rimmed by narrow flat border.

Dimensions of the hypotype no. 34589 are: total length 12 mm., length of cephalon 4 mm., length of thorax 5 mm., length of pygidium 3 mm.; cephalon 7 mm. wide at genal angles, glabella 2.5 mm. wide at base, thorax and anterior end of pygidium 6 mm. wide, thoracic axis 2 mm. wide opposite genal spines and pygidial axis 1.5 mm. wide at anterior end. Represented by numerous detached pygidia and a single, entire dorsal mold.

*Hypotype.*—Univ. Calif. Mus. Paleo. Type Coll. no. 34589.

*Discussion.*—These specimens do not belong to any described species of *Proetus* known to the writer, but poor preservation of the cephalon does not warrant description of a new species.

*Occurrence and range.*—Locality B-5247, Gazelle formation. *Proetus* occurs in the Middle Ordovician-Upper Devonian rocks of Europe, North America, South America, Africa and Asia (Přibyl, 1946).

Order PHACOPIDA Salter, 1864
Suborder CHEIRURINA Harrington and Leanza, 1957
Family CHEIRURIDAE Salter, 1864
Subfamily CHEIRURINAE Salter, 1864
Genus CHEIRURUS Beyrich, 1845
CHEIRURUS sp. cf. C. INSIGNIS Beyrich
Pl. 36, figs. 1–3

*Description.*—Cephalon roughly semicircular in outline, slightly convex, with genal angles apparently produced into short spines; glabella large, constituting more than one-third of cephalon, expanded anteriorly, reaching frontal margin, and convex but not elevated much above cheeks; three pairs of lateral furrows impressed in glabella, all slope gently backward with anterior furrows nearly crossing glabella, posterior pair open directly into neck furrows near middle of glabella and isolate triangular basal lobes; fixed cheeks larger than free cheeks; facial sutures extend from in front of genal angles inward to eyes and then obliquely forward, cutting anterior margin in front and on each side of glabella; cheeks slightly convex and marked laterally by marginal furrows continuous with posterior cheek furrows; eyes apparently small; sur-

face of cheeks pitted, glabella smooth; number of thoracic segments unknown; axial lobe less than one-third width of thorax; axis moderately convex, bounded by sharp dorsal furrows, and tapering gently backward; each pleuron divided by node-like constriction into an inner third and outer two-thirds; inner third of pleuron cut by deep diagonal furrow, outer two-thirds produced into broad spine bending posteriorly; pygidium broad and short; axis with three distinct annulations and fourth rudimentary one; pleura flat, broad, and produced into three pairs of broad spines directed obliquely outward and backward, posterior pair of spines much shorter than others; inner third portions of pleura marked by oblique deep furrows.

Dimensions of a cephalon (hypotype no. 34590) are: length of cephalon 6 mm., width of cephalon about 16 mm., width of glabella at base 4 mm., width of glabella at anterior end 6 mm.

Dimensions of largest pygidium (hypotype no. 34591) are: length 3 mm., width at anterior margin 6 mm., width of axis anteriorly 1.5 mm. Collection consists of two cephala, detached thoracic segments and two pygidia.

*Hypotypes.*—Univ. Calif. Mus. Paleo. Type Coll. nos. 34590, 34591, 34592.

*Discussion.*—Only incomplete specimens were collected and the characters needed for specific identification are obscure or missing. No significant differences, however, could be found between the fragmentary remains and the descriptions and illustrations of *C. insignis* of Barrande (1852, pl. 41, figs. 1–13), Barton (1915, p. 129, fig. 19), Prantl and Přibyl (1947, p. 14, pl. 5, figs. 5,6). Among the American cheirurids, *Cheirurus welleri* (Raymond, 1916, p. 34, pl. 3, fig. 6; pl. 4, figs. 7,8) closely resembles the Gazelle specimens and is also characterized by anterior lateral furrows that nearly cross the glabella. The pygidium of *C. welleri* is not certainly known, preventing more thorough comparison.

*Occurrence and range.*—Locality B-5247, Gazelle formation. *C. insignis* occurs in the Llandoverian-Wenlockian Motol beds, $e_{a2}$ of Bohemia. The genus *Cheirurus* has a cosmopolitan distribution and is almost exclusively Silurian, although its first representatives occur in the Upper Ordovician (Prantl and Přibyl, 1947). *C. welleri* occurs in the Niagaran at Wauwatosa, Wis., the Clinton of New York, the Waldron of Indiana, Silurian of Tennessee, and Guelph of Ontario (Raymond, 1916, p. 35).

Family ENCRINURIDAE Angelin, 1854
Subfamily ENCRINURINAE Angelin, 1854
Genus ENCRINURUS (CROMUS)
Barrande, 1852
ENCRINURUS (CROMUS) BEAUMONTI
(Barrande)
Pl. 36, figs. 4–9

*Encrinurus (Cromus) beaumonti* BARRANDE, 1852, pl. 43.

*Description.*—Cephalon sub-trigonal in outline and moderately convex; glabella prominent, inflated anteriorly and bounded by deep dorsal furrows; four pairs of short (notch-like) lateral furrows divide glabella into four lateral lobes and an anterior lobe; first three lobes and anterior lobe sub-equal, basal lobes about one-half as large; occipital furrow deep and rounded; occipital segment narrow; fixed cheeks moderately convex with deep posterior cheek furrows originating at dorsal furrows and extending nearly to genal angles; genal angles rounded and not produced into genal spines; entire surface of cephalon, including occipital segment and posterior marginal border, covered with rounded tubercles; three small entire specimens have eleven thoracic segments each; thorax with deep axial furrows; axis strongly convex and slightly tapering posteriorly; pleural lobes flat with sharp downward flexure near margins; pleura ridged, straight in flat region, but curved slightly anteriorly starting at downward flexure; pleural furrows continuous with articulating furrows of thorax; tiny tubercles line pleural ridges and axial rings; pygidium trigonal, wider than long; axis strongly convex, bounded by deep dorsal furrows, and extending nearly to posterior margin; about eleven axial rings extend continuously across axis becoming finer and less distinct posteriorly; pleural lobes with nine paired ribs; last pair apparently fused to axis; first five rib furrows continuous with ring furrows; six axial rings, two without corresponding ribs occur back of fifth ring; ribs arched backward and last two pairs almost com-

pletely paralleling axis; circular-shaped notches, developed on ends of rib furrows produce serrate margin; axial rings tuberculate with smaller tubercles produced on ribs.

Dimensions of small, nearly complete specimen (hypotype no. 34593) are: total length 10 mm., length of cephalon 3 mm., length of thorax 4 mm., length of pygidium 3 mm., width of pygidium at anterior end 3 mm., width of cephalon between tips of genal angles 6 mm., greatest width of glabella 2.5 mm., width of axis at occipital segment 1.5 mm.

Dimensions of large cephalon (hypotype no. 34594) are: length along median line 8 mm., distance between tips of genal angles 13 mm., greatest width of glabella 4 mm., width of occipital segment 3 mm.

Dimensions of large pygidium (hypotype no. 34598) are: length 7 mm., width at anterior margin 9 mm., width of axis at anterior margin 2 mm. Collection consists of numerous disassociated pygidia, cephala and several nearly complete specimens.

*Hypotypes.*—Univ. Calif. Mus. Paleo. Type Coll. nos. 34593, 34594, 34595, 34596, 34597, 34598.

*Discussion.*—The Gazelle specimens have smaller tubercles on their cheeks and glabellae than does the Bohemian lectotype and lack tubercles on the posterior borders and occipital rings. Smooth or sparsely tuberculate pygidia and cephala, however, are also present in the Gazelle collection.

According to Prantl and Přibyl (personal communication, 1960) these differences in carapace ornamentation result from different modes of preservation and are not of specific value.

Detached free cheeks (about 3 mm. wide and 10 mm. long) with raised borders and containing a small eye near the middle of their inner edges probably belong to the same species.

*Occurrence and range.*—Locality B-5247, Gazelle formation. *E. (Cromus) beaumonti* is restricted to the Silurian in Bohemia and the genus *Encrinurus* attained cosmopolitan distribution in Middle Ordovician-Silurian time.

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# AMMONITES FROM THE SEABEE FORMATION (CRETACEOUS) OF NORTHERN ALASKA

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ABSTRACT—The Seabee formation, 400–1,800 feet thick, contains two ammonite faunas that are assigned to the Turonian stage of the Upper Cretaceous. These ammonites reveal a mixing of elements from the Atlantic and Pacific faunal realms. The species of *Scaphites* and *Watinoceras* are Atlantic types whereas the species of *Otoscaphites*, *Borissiakoceras*, and *Proplacenticereas* seem to have a Pacific source. A connection of the Western Interior seaway with the Pacific Ocean via the Arctic Ocean along northern Alaska seems likely. New species described are *Scaphites subdelicatulus*, *Otoscaphites seabeenis*, *Borissiakoceras inconstans*, and *B. ashurkoffae*.

## INTRODUCTION

DURING the field seasons of 1946, 1947, 1949, 1951, and 1952, U. S. Geological Survey parties collected well preserved ammonites from the Seabee formation in connection with the U. S. Navy's oil exploration program in Naval Petroleum Reserve No. 4 and adjacent areas in northern Alaska. These collections, which came from nine localities, represent two zones belived to be of early Turonian age. Both faunas are of unusual interest in that they reveal a mixing of Atlantic and Pacific species. Five of the species are new. The types of the new species as well as other figured specimens are deposited in the United States National Museum, Washington.

## STRATIGRAPHY

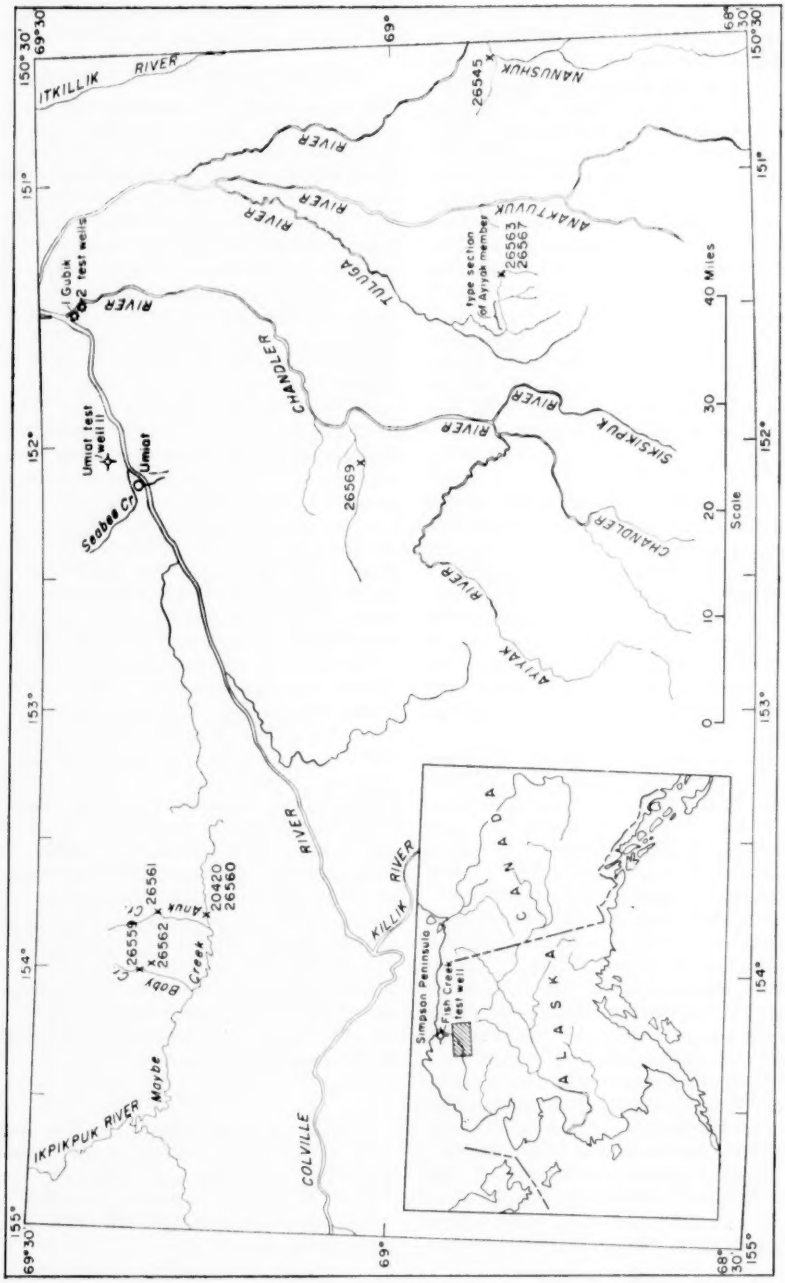
A series of Upper Cretaceous rocks containing the ammonite *Scaphites*, and several species of pelecypods, including *Inoceramus*, were first mapped in northern Alaska by Schrader in 1904 (p. 80). The first formal definitions and descriptions of these Upper Cretaceous formations were published in 1951 by Gryc, Patton, and Payne, who named the Seabee member of the Schrader Bluff formation from exposures along Seabee Creek near Umiat (text-fig. 1). The member was described as 450 feet of predominantly shale with a distinctive 150-foot low-grade oil shale at the top. It was considered to be the age equivalent of the Greenhorn limestone of the western interior of the United States on the basis of a characteristic fauna including *Scaphites delicatulus* Warren and *Inoceramus labiatus* (Schlotheim).

The Seabee member was redefined as the Seabee formation by Whittington (1956, p. 246–248) because the distinctive shale and characteristic fauna had a greater stratigraphic and geographic range than was previously known. He designated the rocks penetrated in Umiat test well 11 between 545 and 2,040 feet as the type section. This section is predominantly a dark clay shale with numerous laminae and thin beds of bentonite, and some concretions and thin beds of dark-gray limestone. Siltstone and very fine-grained sandstone are minor constituents.

The upper part of the Seabee formation was described and named the Ayiyak member by Detterman (1956) from exposures along the Ayiyak River. The type locality is along the nearby east fork of the Tuluga River (see text-fig. 1) and consists of 360 feet of greenish-gray, somewhat tuffaceous, siltstone, silty shale, and sandstone. The member grades northward into shale. Jones and Gryc (in press) report *Inoceramus cuvieri* Sowerby from two localities in the Ayiyak member and also with *I. labiatus* (Schlotheim) in the upper part of the unnamed lower unit of the Seabee formation. No ammonites have been found in the Ayiyak member.

The Seabee formation is present throughout the central part of northern Alaska, but it has not been identified west of longitude

[1] Publication authorized by the Director, U. S. Geological Survey.




TEXT-FIG. 1—Localities in northern Alaska from which ammonites were collected from the Seabee formation.

156° W. or east of longitude 150° W. Variations in thickness and lithology indicate a pronounced thinning to the west and a slight thinning and gradation to shale to the north. Near locality 26545 on the Nanushuk River the Seabee formation is about 1,800 feet thick but thins to less than 400 feet west of the Chandler River. In the Umiat (Collins, 1958, p. 74) and Gubik (Robinson, 1958, p. 210,211) test wells it is 1,500 feet thick but thins westward to less than 400 in the Maybe Creek area. In Fish Creek test well no. 1, about 165 miles north of Umiat, it is reported to be 1,235 feet thick (Robinson & Collins, 1959, p. 502,503), and in the subsurface of the Simpson Peninsula, about 180 miles northwest of Umiat, the Seabee formation is believed to be about 1,200 feet thick (Robinson, 1959, p. 526,527).

## AGE

The two ammonite faunas from the unnamed lower unit of the Seabee formation are best assigned an early Turonian age. In terms of the standard reference sequence for the Western Interior of the United States the lower unit of the Seabee formation seems to correlate with the upper part of the Greenhorn limestone and to represent the faunal zones of *Sciponoceras gracile* and *Inoceramus labiatus* (Cobban and Reeside, 1952, p. 1017,1018).

The younger Seabee ammonite fauna can be dated with little question. It contains *Scaphites delicatulus* Warren and *Watinoceras reesidei* Warren in association with *Inoceramus labiatus* (Schlotheim), an assemblage known from lower Turonian rocks of Canada and the United States.

The older fauna cannot differ much in age inasmuch as it also contains *Inoceramus labiatus* (Jones & Gryc, in press). Of the three ammonites present, only one species, *Otoscaphites perrini* (Anderson), has been known previously, and its age has been variously stated as Cenomanian (Reeside, 1927, p. 33), questionable late Cenomanian (Anderson, 1958, p. 252), and questionable Turonian (Matsumoto, 1953, p. 17). Because of the close affinities of the new species *Scaphites subdelicatulus* with *S. delicatulus* Warren from the *Inoceramus labiatus* zone and *S. delicatulus* var. *greenhornensis* Cobban from the *Sciponoceras gracile* zone, the writers assign the older Seabee ammonite fauna to the earliest Turonian.

## PALEOGEOGRAPHIC INTERPRETATION

Both ammonite faunas from the lower member of the Seabee formation contain species that are interpreted by the writers as representing a mixture of elements of the Atlantic and Pacific faunal realms. The species of *Otoscaphites*, which have very depressed whorls with coronate cross sections and peculiar apertures, resemble scaphites from California, Oregon, and Japan. The species of *Scaphites*, on the other hand, are typical of the types found in the Western Interior of the United States and northern Europe. The one species of *Watinoceras* is found in the Western Interior region and is closely related to forms from Turkestan and western Africa. The species of *Borissiakoceras* are very different from the Turonian species of the Western Interior region and from the Turonian species of Turkestan. An Arctic source seems likely inasmuch as this genus is unknown from the Pacific faunal realm. The fragments of *Proplacenticeras* are also unlike anything known from the Western Interior, Europe, or the Pacific area.

During the Late Cretaceous the Western Interior sea was connected to the Atlantic Ocean through part of Texas and Mexico. Accordingly, the Western Interior region and Europe have many ammonite species in common. The Western Interior seaway, however, was separated from the Pacific Ocean by a persistent highland area occupying western Mexico, western Arizona, Nevada, eastern Oregon and Washington, most of Idaho, central British Columbia, part of Yukon Territory, and possibly part of north-central Alaska. Marine connections of the Western Interior sea with the Pacific Ocean may have been by way of the Arctic Ocean along the present Arctic slope of Alaska or possibly by straits extending through parts of the present Brooks Range area.

## LOCALITY DATA

*U.S.G.S. Mesozoic locality 20420.*—North bank of Maybe Creek 1½ miles above junction with Anuk Creek. Lat. 69°16′ N., long. 153°47′ W. Seabee formation, 350–360 feet below top of the unnamed lower unit. R. G. Ray, 1946.

*Scaphites delicatulus* Warren
*Otoscaphites seabeensis* n. sp.
*Proplacenticeras?* sp.
*Watinoceras reesidei* Warren
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26545.*—West bank of Nanushuk River about 6½ miles below junction with May Creek. Lat. 68°50′30″ N., long. 150°33′ W. Seabee formation, 860 feet above the base. E. J. Webber, 1947.

*Scaphites subdelicatulus* n. sp.
*Otoscaphites perrini* (Anderson)
*Borissiakoceras inconstans* n. sp.

*U.S.G.S. Mesozoic locality 26559.*—Baby Creek, at fork 5½ miles above mouth. Lat. 69°21′ N., long. 154°00′ W. Seabee formation, 140–150 feet below top of the unnamed lower unit. A. N. Kover, 1949.

*Otoscaphites seabeensis* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26560.*—North bank of Maybe Creek 1½ miles above junction with Anuk Creek. Lat. 69°16′ N., long. 153°47′ W. Seabee formation, 360–370 feet below top of the unnamed lower unit. W. P. Brosgé, 1949.

*Scaphites delicatulus* Warren
*Otoscaphites seabeensis* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26561.*—Anuk Creek, bend about 5 miles above mouth. Lat. 69°20′ N., long. 153°47′ W. Seabee formation, 240–250 feet below top of the unnamed lower unit. W. P. Brosgé, 1949.

*Otoscaphites seabeensis* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26562.*—East bank of tributary that enters Baby Creek about 3½ miles above mouth. Lat. 69°20′ N., long. 153°59′ W. Seabee formation, 250–260 feet below top of the unnamed lower unit. W. P. Brosgé, 1949.

*Scaphites delicatulus* Warren
*Otoscaphites seabeensis* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26563.*—North bank of eastern fork of Tuluga River. Lat. 68°50′45″ N., long. 151°25′ W. Seabee formation, 100–150 feet below top of the unnamed lower unit. George Gryc, 1951.

*Scaphites delicatulus* Warren
*Otoscaphites seabeensis* n. sp.
*Proplacenticeras?* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26567.*—North bank of eastern fork of Tuluga River. Lat. 68°50′45″ N., long. 151°25′ W. Seabee formation, 70 feet below top of the unnamed lower unit. R. L. Detterman, 1952.

*Scaphites delicatulus* Warren
*Otoscaphites seabeensis* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

*U.S.G.S. Mesozoic locality 26569.*—On a small tributary of Chandler River about 12½ miles north of junction with Siksikpuk River. Lat. 69°02′15″ N., long. 152°04′ W. Seabee formation, 200–250 feet above the base. R. S. Bickel, 1952.

*Scaphites delicatulus* Warren
*Otoscaphites seabeensis* n. sp.
*Borissiakoceras ashurkoffae* n. sp.

## SYSTEMATIC DESCRIPTIONS

Class CEPHALOPODA
Order AMMONOIDEA
Family SCAPHITIDAE Meek, 1876
Subfamily SCAPHITINAE Meek, 1876
Genus SCAPHITES Parkinson, 1811

### SCAPHITES SUBDELICATULUS, n. sp.

Pl. 37, figs. 1–15; text-fig. 2c

*Scaphites delicatulus* WARREN. GRYC, *in* PAYNE and OTHERS, 1951, sheet 3, figs. 20-6a,6b.

*Diagnosis.*—This species is characterized by its small size, inflated form, umbilical swelling, ventrolateral bullae, and tendency toward loss of ribbing on the younger part of the body chamber. The suture pattern is simple and has bifid lobes and saddles on the external part.

*Material.*—The collection from which the types were selected consists of 14 complete adults and fragments of 35 other individuals from locality 26545. The specimens are from medium-gray hard limestone concretions that contain abundant dark-brown fish bones and scales and bits of black carbonized fossil wood.

*Description.*—The 14 complete adults

TABLE 1—RIB COUNTS ON 12 ADULT SPECIMENS OF *Scaphites subdelicatulus*

| USNM Specimen | Length (mm.) | Total ribs | | Body chamber ribs | |
|---|---|---|---|---|---|
| | | Primaries | Secondaries | Primaries | Secondaries |
| 130795c | 17.8 | 21 | | 10 | |
| 130796a | 20 | 20 | 90 | 9 | 50 |
| 130796b | 20.6 | 23 | 90 | 12 | 50 |
| 130796c | 22.9 | 23 | 78 | 12 | 43 |
| 130796d | 24.7 | | | 10 | 39 |
| 130795a | 24.7 | 21 | 80 | 10 | 40 |
| 130796e | 24.9 | | | 7 | |
| 130796f | 25.1 | 20 | 73 | 9 | 34 |
| 130796g | 25.1 | | | 11 | 47 |
| 130796h | 25.2 | 23 | 74 | 10 | 36 |
| 130796i | 25.7 | | | 10 | 34 |
| 130796j | 26.5 | 21 | | 10 | 37 |
| 130794 | 27.8 | 22 | | 11 | |
| 130795b | 33 | 24 | 75 | 11 | 33 |

range in length from 17.8 to 33 mm. All are very stout and have depressed whorl sections that are wider than high. The venter is broadly rounded and the flanks are slightly flattened. The umbilicus is very small. Most specimens have an umbilical swelling at the base of the body chamber. The body chamber is widest near its adapical end; it tapers gradually toward the aperture which is enclosed by a conspicuous constriction.

Ornamentation consists of nearly straight primary ribs that end, on the body chamber, in bullae, and numerous secondary ribs that arise from the primaries and between them. Rib counts on the complete adults at hand show an average of 21.8 primaries and 80 secondaries of which 10.2 primaries and 40.3 secondaries are on the body chamber.

The secondary ribs are equispaced. They show apicad bending on crossing the venter on the septate coil. The secondaries straighten on the older part of the body chamber, and, on some individuals, these ribs arch forward slightly on approaching the aperture. The primary ribs slant forward on the flanks of the body chamber and ter-

→

TEXT-FIG. 2

*a,b,o—Scaphites delicatulus* Warren. *a*, suture ×3 at diameter of 16 mm. of a specimen, USNM 130803, from loc. 26563; *b*, suture ×3 at diameter of 18 mm. of a specimen, USNM 130801c, from loc. 26560; *o*, cross section ×3 at diameter of 20 mm. of a septate coil, USNM 130801d, from loc. 26560.

*c—Scaphites subdelicatulus*, n. sp. Second from last suture ×3 of the holotype, USNM 130794, from loc. 26545.

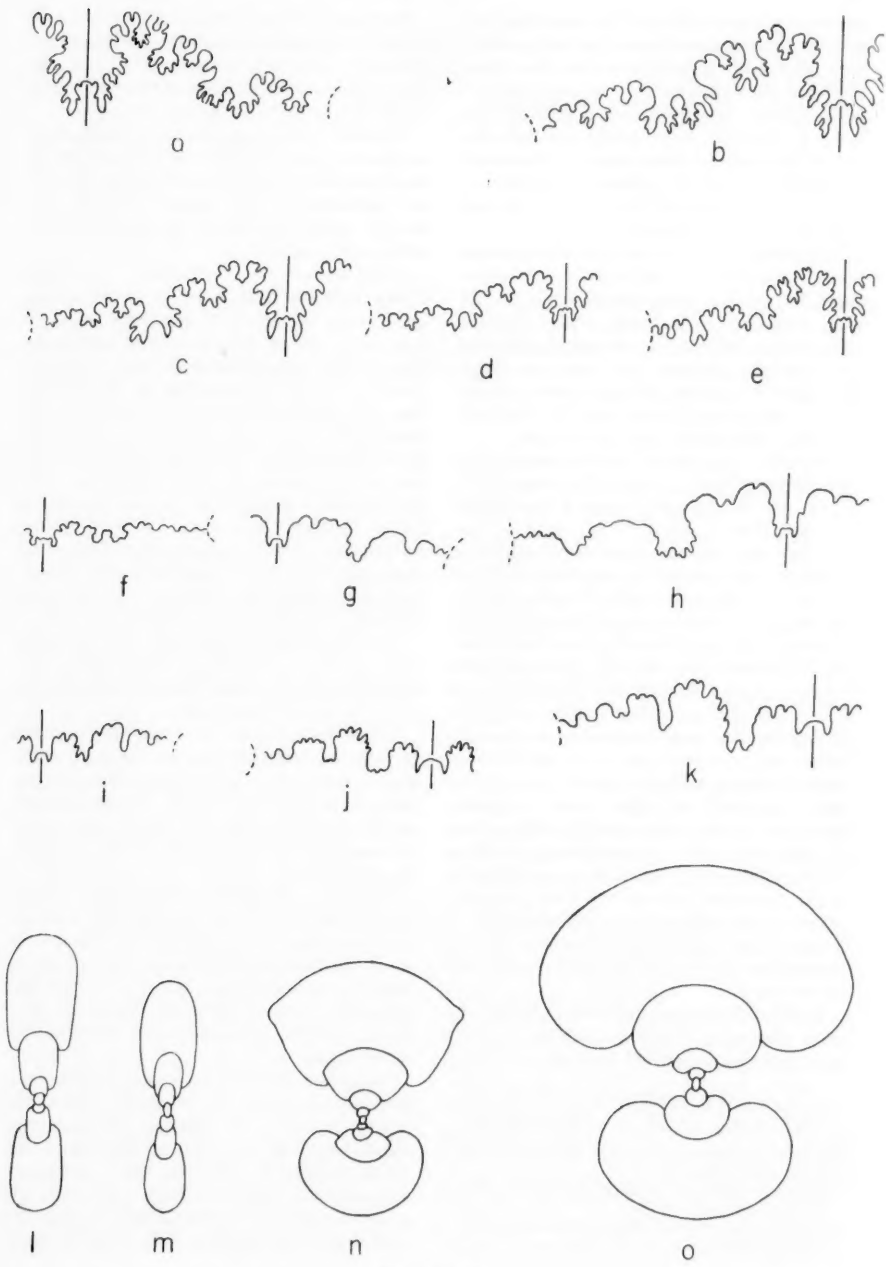
*d,e,n—Otoscaphites seabeensis*, n. sp., from loc. 26560. *d*, fourth from last suture ×4 of the holotype, USNM 130805; *e*, sixth from last suture ×4 of a paratype, USNM 130806b (Pl. 2, figs. 23–27); *n*, cross section ×3 at diameter of 14 mm. of an adult, USNM 130806c.

*f—Proplacenticeras* n. sp. Suture ×4 at diameter of 11 mm. of a specimen, USNM 130809, from loc. 26563.

*g,h—Watinoceras reesidei* Warren, from loc. 20420. *g*, second from last suture ×4 of an adult, USNM 130815c (Pl. 2, figs. 48,49); *h*, suture ×4 of a coarsely ribbed specimen, USNM 130815a (Pl. 2, figs. 44, 45.

*i,l—Borissiakoceras inconstans*, n. sp., from loc. 26545. *i*, last suture ×4 of the holotype, USNM 130798; *l*, cross section ×3 of an adult, USNM 130799c.

*j,k,m—Borissiakoceras ashurkoffae*, n. sp. *j*, eighth from last suture ×4 of an adult, USNM 130812, from loc. 26569 (Pl. 2, figs. 40,41); *k*, sixth from last suture ×4 of holotype, USNM 130810, from loc. 20420 (Pl. 2, figs. 42,43); *m*, cross section ×2 at diameter of 19 mm. of an adult, USNM 130813b, from loc. 26569.




TEXT-FIG. 2

minate in low bullae at the ventrolateral margin. Internal molds of adult body chambers with bits of shell attached show that the secondary ribbing may or may not extend entirely through the shell material (pl. 1, fig. 5). Internal molds of the younger one-fourth to three-fourths of some of these body chambers are faintly ribbed to smooth.

The suture pattern is of about average complexity for the genus.

The holotype is an internal mold retaining much of the shell on the septate part and a small bit on the body chamber. It is 27.8 mm. long, 24.2 mm. high, and 17.2 mm. wide. It has 22 primary ribs equally divided between the septate coil and the body chamber. Secondary ribs are faintly visible on the apicad and orad parts of the body chamber; the middle part is smooth.

*Remarks.*—*Scaphites subdelicatulus* most closely resembles *S. obliquus* Sowerby (1813, p. 54, pl. 18, figs. 4–7) and *S. delicatulus* Warren (1930, p. 66, pl. 3, fig. 3; pl. 4, figs. 7,8) in size, shape, stoutness, umbilical swelling, and general arrangement of the ribbing including the apicad bending of the secondaries on the venter of the septate coil. *Scaphites obliquus* differs by its greater number of primary ribs, lack of equispacing of the secondaries on the body chamber, and strong ribbing on internal molds. *Scaphites delicatulus* has small tubercles in place of bullae and internal molds show that the secondary ribbing extends entirely through the shell material on the body chamber. *Scaphites subdelicatulus* readily differs from *S. delicatulus* var. *greenhornensis* Cobban (1951, p. 18, pl. 1, figs. 1–3) by equispacing of the secondary ribs on the body chamber.

*Occurrence.*—*Scaphites subdelicatulus* is known only from its type locality where it occurs in the Seabee formation 860 feet above the base.

*Types.*—Holotype, USNM 130794; figured paratypes, USNM 130795a–c; unfigured paratypes, USNM 130796a–j.

SCAPHITES DELICATULUS Warren

Pl. 37, figs. 16–24; text-figs. 2a,2b,2o

*Scaphites delicatulus* WARREN, 1930, p. 66, pl. 3, fig. 3; pl. 4, figs. 7,8.
*Scaphites brittonensis* MOREMAN, 1942, p. 215, pl. 34, figs. 1,2; text-fig. 2r.
*Scaphites delicatulus* WARREN. WARREN, 1947, p. 123, pl. 29, fig. 5.

*Diagnosis.*—This species, about average size for the genus, is marked by its stoutness, uniformly spaced secondary ribs, and numerous primary ribs that end in small round nodes. The suture pattern is simple.

*Material.*—Fourteen complete adults and fragments from 50 other individuals are at hand from limestone concretions in the Seabee formation. The preservation is unusually good and some specimens retain their nacrous shell.

*Description.*—The original specimen (Univ. Alberta Geol. Mus. Ct. 419) figured by Warren is a small robust form about 23 mm. long. An umbilical swelling marks the base of the body chamber. Warren's illustration is poor, but according to his description the ornament consists of primary ribs terminating in prominant sharp nodes, and from these two or three secondary ribs and one or two intercalated secondaries cross the venter evenly. The second specimen (Univ. Alberta Geol. Mus. Ct. 957) figured by Warren (1947) is much larger (about 38 mm. long) and has a total of about 30 primary ribs and 97 secondaries. Each primary rib ends in a small but conspicuous node.

The adult specimens from Alaska range in length from 22 to 50 mm. Rib counts for a representative sample (locality 26560) are given in the following table.

All of the Alaskan specimens show either straightening or slight apicad bending of the ribs as they cross the venter on the younger part of the last septate coil. The secondaries on the body chamber are evenly spaced and ordinarily show no forward arching on crossing the venter.

*Remarks.*—*Scaphites brittonensis* Moreman (1942, p. 215, pl. 34, figs. 1,2; text-fig. 2r) from Texas seems to be the same species as *S. delicatulus*. Moreman's figured specimen is smaller than Warren's type but otherwise much like it in form and ornament. Larger specimens are now known from Texas.

*Scaphites delicatulus* closely resembles *S. geinitzi* d'Orbigny (1850, p. 214) from the upper Turonian of Europe. The specimen figured by Geinitz (1846, p. 301, pl. 12, fig. 1) as *S. aequalis* Sowerby has a more pronounced umbilical swelling, and nodes are present only on the body chamber. Schlüter (1872, p. 75, pl. 23, figs. 12–22; pl. 27, fig. 9)

TABLE 2—RIB COUNTS ON 6 ADULT SPECIMENS OF *Scaphites delicatulus*

| USNM Specimen | Length (mm.) | Total ribs | | Body chamber ribs | |
|---|---|---|---|---|---|
| | | Primaries | Secondaries | Primaries | Secondaries |
| 130801a | 28 | 18 | 71 | 9 | 28 |
| 130801b | 31 | 25 | | 13 | 32 |
| 130802a | 36.7 | 25 | 83 | 12 | 38 |
| 130802b | 37.5 | 23 | 87 | 10 | 33 |
| 130802c | 40.7 | 23 | 74 | 8 | 30 |
| 130802d | 41.4 | 25 | 71 | 13 | 31 |

and Fritsch and Schlönbcah (1872, p. 42, pl. 13, figs. 7,8,10,12a,12b; pl. 14, fig. 11) figured several species as *S. geinitzi*, but only the specimen shown on Schlüter's pl. 23, fig. 14 closely resembles Geinitz's form. This specimen of Schlüter differs from *S. delicatulus* by its sigmoidal primary ribs on the body chamber and the restriction of the nodes to the body chamber. Roemer (1870, p. 320, pl. 35, fig. 6), Geinitz (1874, p. 191, pl. 35, figs. 1–4), and Woods (1896, p. 81, pl. 3, figs. 5–7) have figured specimens similar to this one of Schlüter. The body chamber of a scaphite from East Greenland figured by Donovan (1953, p. 120, pl. 25, fig. 1) as *Scaphites* sp. cf. *geinitzi* resembles *S. delicatulus* by the straight primary ribs ending in nodes but differs by the greater number of primaries and by the lack of equispacing of the secondaries.

*Occurrence.*—*Scaphites delicatulus* was collected at the following localities in northern Alaska: 20420, 26560, 26562, 26563, 26567, 26569. In Canada this species is known from the base of the Upper Cretaceous just west of Bear Rock in the vicinity of Fort Norman in the Mackenzie River drainage (Warren, 1947, p. 123; Stelck and Wall, 1954, p. 14), and from the Kaskapau formation in the Spirit River and Smoky River areas of the western Peace River plains of west-central Alberta (Warren, 1930, p. 58,66; Gleddie, 1949, p. 528,529, text-fig. 2). McLearn (1937, p. 115) has recorded *Scaphites* cf. *delicatulus* from the lower part of the Alberta shale much farther to the south in southwestern Alberta.

In the Western Interior of the United States *S. delicatulus* has been collected by Cobban from the Cone calcareous member of the Marias River shale on the Sweetgrass arch of north-central Montana, and from the upper part of the Greenhorn formation on the north flank of the Black Hills uplift in southeastern Montana. The species has been recorded from the Cody shale near Hardin, Montana (Richards, 1955, p. 52) and Buffalo, Wyoming (Hose, 1955, p. 98).

In Texas, *Scaphites delicatulus* has been found in the Eagle Ford shale.

*Types.*—Pleisotypes, USNM 130801a–d, 130802a–d, 130803, 130804.

## Genus OTOSCAPHITES Wright, 1953
## OTOSCAPHITES PERRINI (Anderson)
Pl. 38, figs. 1–12

*Scaphites perrini* ANDERSON, 1902, p. 114, pl. 2, figs. 71–73.
*Scaphites perrini* ANDERSON. YABE, 1910, p. 172, pl. 15, figs. 28a–d,29; text-fig. 3.
*Scaphites ("Yezoites") perrini* ANDERSON. ANDERSON, 1958, p. 252, pl. 25, figs. 6,6a,6b.
*Otoscaphites perrini* (ANDERSON). WRIGHT, 1953, p. 476.

*Diagnosis.*—The small size, stoutness, extremely depressed whorls with coronate sections, and dense evenly spaced weak ribbing characterize this species. The primary ribs terminate in bullae along the umbilical margin.

*Material.*—Seventeen specimens, chiefly adults, are at hand from locality 26545. These are mostly internal molds with bits of shell material attached.

*Description.*—The type specimen (Leland Stanford Junior University 5625) is a small adult 12 mm. long. It has a very depressed cross section, broad ventral area, wide umbilical area, and strong constriction near the aperture. The ventral and umbilical areas meet at a sharp angle along which are small closely spaced bullae. Ribbing on the main part of the venter is scarcely discernible.

The Alaskan adult specimens range in length from 10.8 to 16.6 mm. The smaller

specimens closely match Anderson's type in their degree of stoutness, but the larger forms tend to be broader with more depressed whorl sections. The primary ribs are straight and slant forward across the umbilical wall. They terminate in low inconspicuous bullae from which two or three secondary ribs and one or two intercalaries extend across the venter. These secondaries bend backward slightly along the middle of the venter on the younger part of the last septate coil whereas on the body chamber they tend to cross in a straight line or with a little forward arching. Rib counts, which were possible on only a few specimens, gave 22 to 24 primaries and 68 to 75 secondaries of which 8 to 12 primaries and 30 to 37 secondaries were on the body chamber. The ribbing weakens on the body chamber and tends to disappear on the orad third. Narrow lateral lappets are present at the aperture of adults.

*Remarks.*—The specimens figured by Yabe (1910) from Japan are more strongly ribbed than the American forms. This difference does not seem great enough to warrant a separate species. The American and Japanese forms are more involute than the genotype, *O. bladenensis* (Schlüter).

*Occurrence.*—*Otoscaphites perrini* has been collected in Alaska only at locality 26545. Anderson's specimen came from Oregon.

*Types.*—Plesiotypes, USNM 130797a–c.

OTOSCAPHITES SEABEENSIS, n. sp.
Pl. 38, figs. 13–27; text-figs. 2d,2e,2n

*Diagnosis.*—This is a small species characterized by unusually depressed whorls with the very broad venter and wide umbilicus meeting at a sharp angle. Ornament consists of straight primary (umbilical) ribs ending in small sharp nodes, and, on the venter, numerous secondary ribs. The suture pattern is slightly denticulate and typical for the genus.

*Material.*—Twenty complete adults and fragments of 30 other specimens were available for study. These came from limestone concretions in the Seabee formation at eight localities.

*Description.*—At the smallest diameter (2 mm.) observed, the whorls are depressed with rounded venter, sharply rounded umbilical angle, and steeply inclined umbilical wall. By a diameter of 3.5 mm. the venter becomes more broadly rounded and the umbilical angle sharper. Succeeding whorls keep this coronate section. The flanks, which slope steeply inward, are here considered as part of the umbilicus, and, what would be the ventrolateral margin on ordinary scaphites, is here considered the umbilical shoulder or angle. Near the aperture the body chamber has a strong thick rib bounded by constrictions. From the orad constriction the shell is produced outward in all directions with the greatest amount of extension forming a lateral lappet in line with the umbilical shoulder.

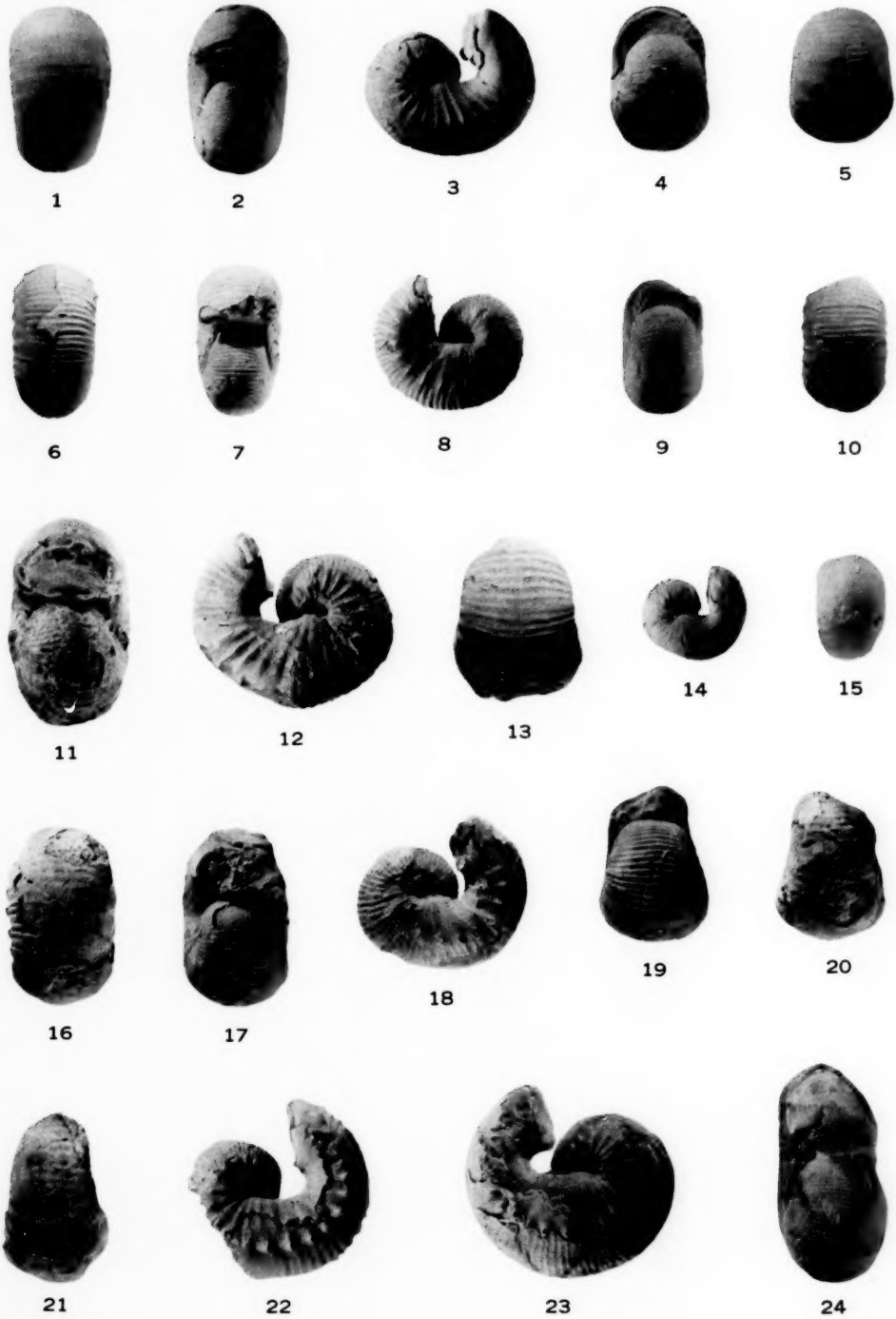
Sculpture consists of forwardly inclined primary ribs that end in small sharp nodes from which nearly straight secondary ribs cross the venter. The primaries are closely spaced and straight to slightly flexuous. Twenty-three to 29 primaries are visible on the adult shell; 10 to 16 are on the body

EXPLANATION OF PLATE 37

All figures ×1

FIGS. *1–15*—*Scaphites subdelicatulus*, n. sp., from loc. 26545. *1–5*, Bottom, top, side, front, and rear views of holotype, USNM 130794; *6–10*, bottom, top, side, front, and rear views of a strongly costate paratype, USNM 130795a; *11–13*, top, side, and rear views of an unusually large paratype, USNM 130795b; *14,15*, side and bottom views of a small adult, paratype, USNM 130795c.

*16–24*—*Scaphites delicatulus* Warren. *16–20*, Bottom, top, side, front, and rear views of pleisiotype USNM 130801a, from loc. 26560; *21,22*, rear and side views of another adult from the same locality, USNM 130801b; *23,24*, side and top views of a densely ribbed specimen, USNM 130804, from loc. 26567.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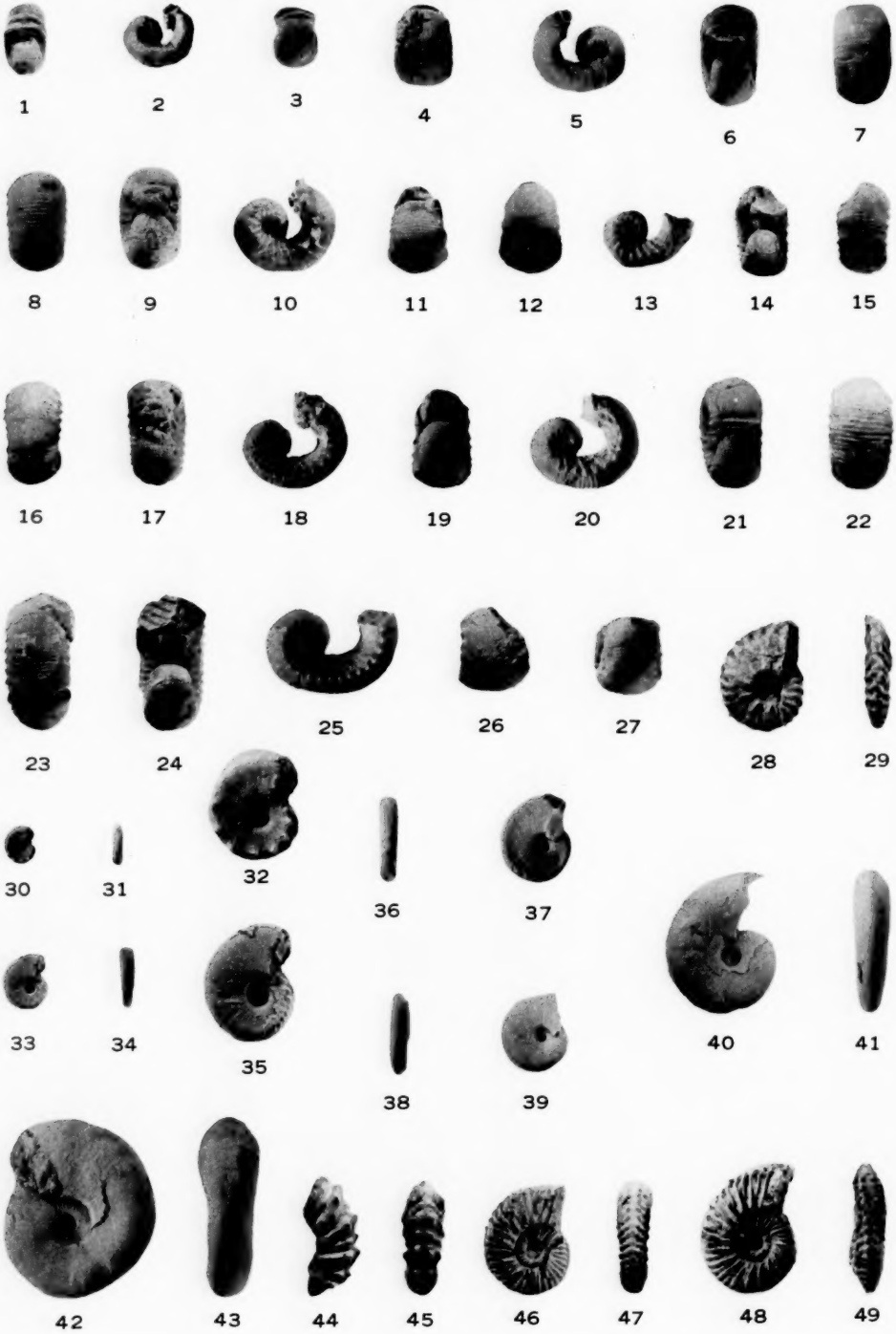
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chamber. Secondary ribs, which are present only on the venter, may number as many as 90 on the adult. Rib counts on a representative sample (locality 26560) are as follows:

The holotype is an internal mold 17.5 mm. long, 15.5 mm. high, and 10.2 mm. wide. It has 29 primary ribs and 75 secondary ribs of which 14 primaries and 34 secondaries are on the body chamber.

TABLE 3—RIB COUNTS ON 6 ADULT SPECIMENS OF *Otoscaphites seabeensis*

| USNM Specimen | Length (mm.) | Total ribs | | Body chamber ribs | |
|---|---|---|---|---|---|
| | | Primaries | Secondaries | Primaries | Secondaries |
| 130807a | 17.5 | | | 16 | 35 |
| 130805 | 17.5 | 29 | 75 | 14 | 34 |
| 130807b | 19.5 | 23 | 90 | 10 | 36 |
| 130806c | 19.6 | 27 | 74 | 14 | 35 |
| 130807c | 20± | | | 16 | 44 |
| 130807d | 20.5 | 24 | 74 | 12 | 34 |

The secondary ribs are bent backward slightly along the middle of the venter on the younger part of the last septate whorl. They straighten on the adjoining part of the body chamber and become arched forward a little nearer the aperture. The secondary ribs are equally spaced, strong on the older part of the body chamber, and weak to scarcely discernible on the younger part.

*Remarks.*—*Otoscaphites seabeensis* resembles *O. perrini* by its depressed whorls with coronate section, but differs chiefly by its stronger ribbing and the presence of sharp nodes intead of inconspicuous bullae. The specimens figured by Yabe (1910, p. 172, pl. 15, figs. 28a–d,29, text-fig. 3) as *Yezoites perrini* (Anderson) resemble the more slender specimens of *O. seabeensis* in

EXPLANATION OF PLATE 38

All figures except *32* and *35* are ×1

FIGS. *1–12*—*Otoscaphites perrini* (Anderson) from loc. 26545. *1–3*, Top, side, and rear views of a small adult, USNM 130797a; *4–7*, rear, side, top, and bottom views of a large adult, USNM 130797b; *8–12*, bottom, top, side, front, and rear views of a strongly costate specimen, USNM 130797c.

*13–27*—*Otoscaphites seabeensis*, n. sp. *13–15*, Side, top, and bottom views of a nearly complete small adult, USNM 130806a, from loc. 26560; *16–19*, bottom, top, side, and front views of the holotype, USNM 130805, from loc. 26560; *20–22*, side, top, and bottom views of paratype USNM 130808, from loc. 26563; *23–27*, bottom, top, side, rear, and front views of a large nearly complete adult, USNM 130806b, from loc. 26560.

*28,29*—*Proplacenticeras?* n. sp. Side and rear views of a specimen, USNM 130809, from loc. 26563.

*30–37*—*Borissiakoceras inconstans*, n. sp., from loc. 26545. *30,31*, Side and rear views of a small specimen showing the ventrolateral nodes, USNM 130799a; *32*, side view of same specimen ×3; *33,34*, side and rear views of the holotype, USNM 130798; *35*, side view ×2 of the holotype; *36,37*, rear and side view of a large paratype, USNM 130799b.

*38–43*—*Borissiakoceras ashurkoffae*, n. sp. *38,39*, Rear and side views of a small paratype, USNM 130813, from loc. 26563; *40,41*, side and rear views of a small adult, USNM 130812, from loc. 26569; *42,43*, side and rear views of the holotype, USNM 130810, from loc. 20420.

*44–49*—*Watinoceras reesidei* Warren, from loc. 20420. *44,45*, Side and rear views of a fragment of a coarsely ribbed variant, USNM 130815a; *46,47*, side and rear views of a densely ribbed specimen, USNM 130815b; *48,49*, side and rear views of the typical form, USNM 130815c.

form and stoutness of the shell and in strength of ribbing, but they lack the pointed nodes and the double constriction near the aperture. Two specimens of the genotype, *O. bladenensis* (Schlüter), figured by Schlüter (1872, p. 77, pl. 23, figs. 5–8) have apertures with a strong rib and adjoining constrictions as in *O. seabeensis*, but the German specimens have evolute septate coils and a different whorl section. *Scaphites patulus* Cobban (1951, p. 20, pl. 1, figs. 23–32), a middle Turonian species from the Black Hills area of the Western Interior of the United States, resembles *O. seabeensis* by the greatly depressed body whorl section and the apicad bending of the ventral ribbing at the junction of the septate coil and body chamber. The Black Hills species differs readily by its coarser sculpture, fewer ribs, and different aperture.

*Occurrence.*—*Otoscaphites seabeensis* has been found at the following localities in northern Alaska: 20420, 26559, 26560, 26561, 26562, 26563, 26567, and 26569. At these localities the species occurs with *Scaphites delicatulus* Warren in the Seabee formation.

*Types.*—Holotype, USNM 130805; figured paratypes, USNM 130806a–c, 130808; unfigured paratypes, USNM 130807a–d.

Family PLACENTICERATIDAE Hyatt, 1900
Genus PROPLACENTICERAS Spath, 1926
PROPLACENTICERAS? n. sp.
Pl. 38, figs. 28,29; text-fig. 2f

*Description.*—Two fragments are at hand. The smallest, representing the inner whorls up to a diameter of 17 mm., is subevolute with an umbilical ratio of 24 percent. It is compressed; the flanks are nearly flat; and the venter narrow. Sculpture consists of sigmoidal primary and secondary ribs, all ending in low clavi that border the venter in alternate positions. The primaries begin from low umbilical bullae. The last complete whorl has 11 primaries and 12 secondaries. The suture pattern is simple and typical of juveniles of the genus. The larger specimen is a fragment of an adult that had smooth flanks. This specimen bears the impression of the venter of the next inner whorl. Although a little distorted, this impression reveals that at a large shell diameter the venter is still flat and bordered by clavi.

*Remarks.*—The writers are not aware of any published figures of either *Proplacenticeras* or *Placenticeras* that have such strongly costate inner whorls of the diameter of the smaller of the Alaskan species.

*Occurrence.*—The smaller specimen is from a limestone concretion about 100 feet below the top of the unnamed lower unit of the Seabee formation at locality 26563 where it is associated with *Scaphites delicatulus*, *Otoscaphites seabeensis*, and *Borissiakoceras ashurkoffae*. The larger specimen is from about 350 feet below the top of the unnamed lower unit at locality 20420 associated with the same species as at locality 26563 with the addition of *Watinoceras reesidei*. In Canada Gleddie (1949, p. 528) records *Proplacenticeras* (as *Placenticeras pseudoplacenta* Hyatt) in association with *Watinoceras* in the Pouce Coupe area of west-central Alberta.

*Figured specimen.*—USNM 130809.

Family ACANTHOCERATIDAE Hyatt, 1900
Subfamily MAMMITINAE Hyatt, 1900
Genus WATINOCERAS Warren, 1930
WATINOCERAS REESIDEI Warren
Pl. 38, figs. 44–49; text-figs. 2g,2h

*Watinoceras reesidei* WARREN, 1930, p. 67, pl. 3, fig. 2; pl. 4, figs. 9–12.
*Watinoceras reesidei* WARREN. WARREN, 1947, p. 122, pl. 30, fig. 6.
*Watinoceras* sp. GRYC, *in* PAYNE AND OTHERS, 1951, sheet 3, fig. 20-5.

*Diagnosis.*—This is a small moderately evolute ammonite that has a compressed section with weakly rounded flanks. Ornament consists of numerous slightly sigmoidal primary and secondary ribs that have two rows of small sharp ventrolateral nodes of which the row nearest the smooth venter is the larger. Umbilical bullae may be present on the primary ribs. The suture, which is simple, has a wide bifid first lateral saddle and narrow first lateral lobe.

*Material.*—Only three specimens, all from locality 20420, are among the fossil collections from Alaska. They are from a limestone concretion and are undistorted.

*Description.*—All five specimens figured by Warren (1930, 1947) are less than 20 mm. in diameter. They are evolute with umbilical ratios of about 40 percent of the total diameter. Ribs are numerous, narrow, sharp,

slightly flexuous, and about equally divided between primaries and secondaries. According to Warren, the last whorl of the holotype has 42 ribs of which 24 are primaries. Umbilical bullae are present on most primaries. Each rib has two small sharp ventrolateral nodes.

The specimens from Alaska are typical of Warren's species. The largest individual, 21 mm. in diameter, has on the last whorl 39 ribs of which every other one reaches the umbilicus. A stout variant with coarse sculpture is represented by a fragment from a specimen of about 20 mm. diamter (Pl. 2, figs. 44,45). It has fewer ribs, stronger primaries, and weaker secondaries. The ventrolateral nodes show elongation in the direction of coiling.

*Remarks.*—*Watinoceras reesidei* has been figured only in the two papers of Warren (1930, 1947). The specimen figured by Reyment (1955, p. 55, text-figs. 25b,25c) as *Watinoceras* aff. *reesidei* from the lower Turonian of the Southern Cameroons is closely related to Warren's species but has more sinuous ribbing and greater number of primaries.

*Occurrence.*—On the Arctic slope of Alaska *Watinoceras reesidei* has been found at only one locality (20420) in the Seabee formation 350 to 360 feet below the top of the unnamed lower unit. Associated fossils include *Scaphites delicatulus, Otoscaphites seabeensis,* and *Borissiakoceras ashurkoffae.* Warren's figured specimens from Canada came from the base of the Upper Cretaceous near Bear Rock in the vicinity of Fort Norman in the lower part of the Mackenzie River valley, and from the lower part of Kaskapau formation on the Smoky River of west-central Alberta. McLearn (1937, p. 114, 115), Gleddie (1949, p. 528, text-fig. 2), Stelck and Wall (1954, figs. 3,4), and Greiner (1955, p. 5), have recorded the species or genus in areas farther west in Alberta, and Douglas (1950, p. 29) records the genus, questionably, far to the south. In the United States *W. reesidei* is known from the upper part of the Cone calcareous member of the Marias River shale in northwestern Montana (Cobban, 1956, p. 1003, 1004), and from the Greenhorn calcareous member of the Cody shale in south-central Montana (Richards, 1955, p. 52).

Family BINNEYITIDAE Reeside, 1927
Genus BORISSIAKOCERAS Arkhangel'skii
BORISSIAKOCERAS INCONSTANS, n. sp.
Pl. 38, figs. 30–37; text-figs. 2i,2l

*Diagnosis.*—A small compressed planulate species characterized by ventrolateral nodes on the inner whorls and smooth adult body chamber. The nodes ordinarily number about 6 per half whorl. The venter is well rounded on the early whorls and broadly rounded on the later whorls.

*Material.*—The type lot consists of 21 specimens from locality 26545. They are well preserved and mostly undistorted. The fossils were found in gray limestone concretions crowded with fish scales and bones.

*Description.*—At the smallest diameter observed, 2 mm., the shell has slightly rounded flanks, well rounded venter, and low rounded ventrolateral nodes spaced 4 to 6 per half whorl. At a diameter of 3 mm. the flanks are flattened and a distinct ventrolateral shoulder is present. The flattened flanks persist on the larger shells but the nodes and conspicuous ventrolateral shoulder disappear. As the nodes disappear they become closely spaced (8 to 14 per half whorl) and may assume a bullate form. The diameter at which the nodes disappear ranges from 3.5 to 12 mm.; most individuals lose the nodes between diameters of 4 and 7 mm. The distinct ventrolateral shoulder ordinarily persists for only a short distance beyond the last node. The adult shell has a broadly rounded venter, flat flanks, and sharply defined umbilicus with ratio of about 20 percent. The shell has sigmoidal growth lines which may be raised locally into low inconspicuous ribs. Most adults are from 10 to 15 mm. in diameter. The dimensions, umbilical ratios, and diameters at which nodes disappear, are given in the following table for the 21 specimens examined.

The suture is normal for the genus. The siphonal lobe is broad, bifid, and moderate in depth. The first lateral saddle, which is as wide as the siphonal lobe, is symmetrically bifid. The first lateral lobe is bifid and about as long as the siphonal lobe but narrower. The second lateral saddle is a little larger than the first and divided into 3 parts by small lobes. The second lateral lobe, which is narrower than the first, is either simple or bifid. The third lateral saddle is bifid and

TABLE 4—DIMENSIONS, UMBILICAL RATIOS, AND DIAMETERS AT WHICH NODES DISAPPEAR ON TYPE LOT OF *Borissiakoceras inconstans*

| USNM Specimen | Diameter (mm.) | Width (mm.) | Umbilicus | | Diameter at which nodes disappear |
|---|---|---|---|---|---|
| | | | mm. | % | |
| 130800a | 4.7 | 1.6 | 1.0 | 21 | |
| 130800b | 5.5 | 1.8 | 1.3 | 24 | 4.0 |
| 130800c | 6.0 | 2.0 | 1.2 | 20 | |
| 130800d | 6.4 | 2.3 | 1.3 | 20 | 6.4 |
| 130799a | 6.5 | 2.0 | 1.7 | 26 | 5.9 |
| 130800e | 6.9 | 2.2 | 1.5 | 22 | |
| 130800f | 7.0 | 2.2 | 1.5 | 21 | |
| 130800g | 7.1 | 2.2 | 1.6 | 23 | 3.5 |
| 130800h | 7.6 | 2.3 | | | 5.0 |
| 130800i | 8.6 | 2.6 | 2.0 | 23 | 5.0 |
| 130800j | 8.8 | 2.4 | 2.0 | 23 | |
| 130798 | 9.5 | 2.8 | 2.5 | 26 | 7.0 |
| 130800k | 9.7 | 3.0 | 1.7 | 18 | |
| 130800l | 10.5 | 3.0 | 2.2 | 21 | |
| 130800m | 10.7 | 3.1 | 2.0 | 19 | |
| 130800n | 12.4 | | 2.3 | 19 | 12.0 |
| 130800o | 13.7 | 4.3 | 2.8 | 21 | |
| 130800p | 14.0 | 3.8 | 2.2 | 18 | |
| 130800q | 14.5 | 4.2 | 2.8 | 19 | |
| 130799b | 14.5 | 3.9 | 3.0 | 21 | |
| 130799c | 15.3 | 3.9 | 3.5 | 23 | |

smaller than the second. The third lateral lobe is small and undivided.

The holotype is a small adult 9.5 mm. in diameter and 2.8 mm. in width. It includes most of the body chamber. This specimen shows all the features of the species; a septate part with ventrolateral nodes decreasing in size but increasing in number toward the body chamber, and the body chamber smooth except for faint dense sigmoidal ribbing.

*Remarks.*—*Borissiakoceras inconstans* differs considerably from the few described species of the genus. *Borissiakoceras reesidei* Morrow (1935, p. 463, pl. 49, figs. 7a,b, pl. 50, fig. 5; text-fig. 8), from the Graneros shale of Kansas, is larger, lacks a distinct ventrolateral shoulder in the young stages, retains ventrolateral nodes out to a diameter of 10 mm., and has a more simple suture pattern. *Borissiakoceras aplatum* Morrow (1935, p. 465, pl. 49, figs. 5a,b; pl. 50, fig. 6; text-fig. 7), from the Carlile shale of Kansas, has a much smaller umbilicus, lacks nodes, and shows a simpler suture pattern. *Borissiakoceras orbiculatum* Stephenson (1955, p. 64, pl. 6, figs. 1–4), from the base of the Eagle Ford shale of Texas, is a larger species with a more pronounced ventrolateral shoulder. From *B. mirable* Arkhangel'skii (1916, p. 55, pl. 8, figs. 2,3; text-fig. 20) of the lower Turonian of Turkestan, *B. inconstans* differs readily by its much smaller umbilicus. The fragment of a body chamber from the Woodbine formation of Texas, described by Stephenson (1952, p. 198, pl. 45, figs. 5,6) as *Euhoplites?* sp., is a larger and more flat-ventered species of *Borissiakoceras* than *B. inconstans*.

*Occurrence.*—*Borissiakoceras inconstans* is known only from locality 26545 where the species occurs in gray limestone concretions in the Seabee formation 860 feet above the base.

*Types.*—Holotype, USNM 130798; figured paratypes, USNM 130799a–c; unfigured paratypes, USNM 130800a–q.

BORISSIAKOCERAS ASHURKOFFAE, n. sp.
Pl. 38, figs. 38–43; text-figs. 2j,2k,2m

*Borissiakoceras* sp. GRYC, *in* PAYNE AND OTHERS, 1951, sheet 3, figs. 20-7a,b.

*Diagnosis.*—This species, about average size for the genus, has a smooth shell and rounded venter without a distinct ventrolateral shoulder. Most specimens lack nodes at any stage. The shell is planulate with an umbilical ratio of about 20 percent. The suture is moderately complex.

*Name.*—The species is named for Mrs.

Tatiana Ashurkoff for her invaluable aid in preparing for study Cretaceous fossils from Alaska.

*Material.*—The species is represented by more than 300 specimens of all sizes. They were collected from limestone concretions at 8 localities. The specimens are very well preserved and many are uncrushed.

*Description.*—At the smallest diameter studied, 1 mm., the whorls are a little broader than high. At a diameter of 1.5 mm. the height and width of the whorls are equal, but at greater diameters the height exceeds the width. The flanks are rounded at diameters less than 2 mm. They become flattened and parallel at diameters between 2 and 4 mm., and at larger diameters they diverge outward slightly The venter is well rounded and merges into the flanks without a distinct ventrolateral shoulder. The umbilicus is sharply defined and has steep walls. Umbilical ratios range between 15 and 26 percent without any conspicuous change between juveniles and adults. Measurements of the umbilical ratios of the specimens (44) from locality 26560 are summarized in the following table.

TABLE 5—Umbilical ratios of *Borissiakoceras ashurkoffae*

| Diameter (mm.) | Umbilical ratio (percent) | Number of specimens |
|---|---|---|
| 2.7– 4.9 | 21.8 | 9 |
| 5 – 9.9 | 20.6 | 15 |
| 10 –14.9 | 17.8 | 11 |
| 15 –19.9 | 18.4 | 7 |
| 20 –22.2 | 17.0 | 2 |

The adult body chamber includes half a whorl. The aperture, which is flared slightly, has a ventral lappet and a smaller lateral lappet. One individual (paratype USNM 130812) has a shallow constriction near the aperture. All specimens have sigmoidal growth lines, and, on some, these may be grouped into faint closely spaced ribs that are strongest near the ventrolateral margin.

Most adults are between 20 and 30 mm. in diameter. The largest specimen (paratype USNM 130811j) observed is 32.5 mm.

Ventrolateral nodes, spaced 6 to 8 per half whorl, are present on some individuals. These nodes ordinarily disappear at a shell diameter between 3 and 6 mm.

The suture is more digitate than that of any described species of the genus.

The holotype is an adult 28.9 mm. in diameter and 10.1 mm. in width.

*Remarks.*—*Borissiakoceras ashurkoffae* differs from *B. inconstans*, n. sp., by its larger size, rounder venter, and lack of nodes on most specimens. *Borissiakoceras ashurkoffae* closely resembles *B. reesidei* Morrow (1935, p. 463, pl. 49, figs. 7a,b; pl. 50, fig. 5; text-fig. 8) from the Graneros shale of Kansas by its size, stoutness, umbilical ratio, and lack of a ventrolateral shoulder. It differs from *B. reesidei* by its more complex suture pattern and the lack of nodes on the inner whorls of most specimens. *Borissiakoceras aplatum* Morrow (1935, p. 465, pl. 49, figs. 5a,b; pl. 50, fig. 6; text-fig. 7) has a much smaller umbilicus.

*Occurrence.*—*Borissiakoceras ashurkoffae* has been found only at localities 20420, 26559–26563, 26567, and 26569 in the Arctic slope of Alaska. There this species occurs in the Seabee formation 70–450 feet below the top of the unnamed lower unit.

*Types.*—Holotype, USNM 130810; figured paratypes, USNM 130812, 130813a, 130813b; unfigured paratypes, USNM 130811a–j, 130814a–rr.

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# MORPHOLOGIC CLASSIFICATION OF SPONGE SPICULES, WITH DESCRIPTIONS OF SILICEOUS SPICULES FROM THE LOWER ORDOVICIAN BELLEFONTE DOLOMITE IN CENTRAL PENNSYLVANIA

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ABSTRACT—Siliceous sponge spicules from the Bellefonte dolomite near Union Furnace, Central Pennsylvania, are described and illustrated. The new species, *Hyalostelia clinopentactinoides*, is described. *Hyalostelia* Zittel and the genotype, *Hyalostelia smithii* (Young and Young), from the Carboniferous of Scotland, are briefly discussed. A morphologic classification for siliceous spicules, based with some modifications upon review of previous work, is presented together with illustrations of major spicule types.

## PURPOSE AND SCOPE

HEXACTINELLID and monaxon sponge spicules from the Lower Ordovician Bellefonte dolomite in Central Pennsylvania are described and, as far as the writer is able to determine, represent the first reported occurrence of siliceous sponge spicules from the Lower Ordovician of the Appalachians. The collection includes several hundred hexactinellid and about 75 monaxon spicules.

In order to describe and classify these spicules, the literature of fossil sponges was reviewed in some detail. It has been found desirable to assemble and summarize existing terminology concerning the morphologic classification of sponge spicules.

The order of presentation is:

*Location and stratigraphic horizon of the Bellefonte spicules*
*Morphologic classification and terminology of sponge spicules*
*Systematic descriptions*
*Morphologic descriptions*
*Ecologic considerations*

## ACKNOWLEDGMENTS

The writer gratefully acknowledges the kind assistance of Dr. Frank M. Swartz, who made many helpful suggestions and criticisms and edited the manuscript. Richard R. Thompson and William B. Wigginton collected rock samples, the insoluble residues of which contained the first observed occurrence of hexactinellid spicules.

The manuscript is a portion of a thesis in Geology submitted in partial fulfillment of the requirements for the degree of Master of Science. The work was supported by the Mineral Conservation Section, College of Mineral Industries, The Pennsylvania State University.

## LOCATION AND STRATIGRAPHIC HORIZON OF THE BELLEFONTE SPICULES

Hexactinellid and monaxon sponge spicules were obtained from insoluble residues of rock samples of Bellefonte dolomite collected from an abandoned quarry near Union Furnace, Huntingdon County, Pennsylvania. The abandoned quarry is located in the area of the 15-minute Tyrone, Pennsylvania, topographic sheet at latitude 40°37′45″ and longitude 78°10′30″, about $1\frac{1}{4}$ miles northwest of Union Furnace. Uppermost beds of the Bellefonte dolomite are exposed at the northwestern extremity of Warner Company limestone quarries, about one mile northwest of Union Furnace, and Bellefonte exposures continue northwestward along a railroad cut of the main line of the Pennsylvania Railroad and along State Highway 350, into the abandoned quarry, 150 yards north of the Highway.

The studied hexactinellid and monaxon sponge spicules occur in separate horizons, respectively 940 and 935 feet, as measured, stratigraphically below the top of the Bellefonte formation. Hexactinellid spicules were found in extraordinary abundance in a quarter-inch band of dolomite about five

feet above the lowermost beds exposed in the eastern part of the abandoned quarry, and a few scattered spicules were obtained several inches above and below the band. About 500 spicules were liberated from about five cubic inches of the band by digesting the dolomite in 3-Normal hydrochloric acid. Monaxon spicules are present in moderate abundance in a two-inch layer of clastic dolomite about five feet above the hexactinellid horizon. The monaxon spicule horizon is located within a horizon containing prominent nodules of chert: some of the chert nodules preserve a few brachiopod and questionable gastropod shells.

Hexactinellid spicules were observed initially by the writer during the examination of insoluble residues from the Bellefonte dolomite of the Union Furnace section. The insoluble residues had been prepared from rock samples taken by R. R. Thompson and W. B. Wigginton at stratigraphic intervals of two feet, beginning 100 feet below the top of the Bellefonte formation and descending to 1050 feet. Hexactinellid spicules occur in the residues from samples obtained at 938, 940, 952, 1016, and 1030 feet below the top of the formation, although only those spicules from the 940-foot level have been studied. Resampling furnished additional hexactinellid spicules from the 940-foot horizon and revealed the presence of the monaxon spicules at 935 feet, which were not observed in the initial residues. Other parts of the formation were not resampled.

## MORPHOLOGIC CLASSIFICATION AND TERMINOLOGY OF SPONGE SPICULES—GENERAL RELATIONS OF SPICULE TYPES

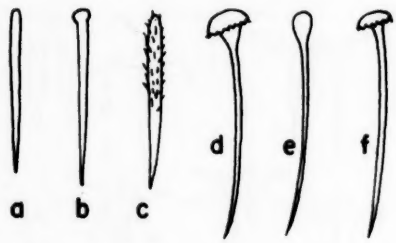
Spongologists have developed an extensive terminology concerning the morphologic classification of sponge spicules whereby a form name is applied to spicules of similar architectural design. The following morphologic classification and accompanying terminology are based upon a review of sponge literature, including especially the work of Hyman (1940), although several of the terms are modified and some new terms are introduced. Spicules are classed according to six major architectural types—namely monaxons, tetraxons, triradiates, triaxons, polyaxons, and desmas—each of which is subdivided so that there is a total of about 70 subtypes. The types and subtypes are briefly defined and indexed with illustrations given in text-figures.

Major considerations in study of the relation of spicule types to sponge biologic taxa include the following: 1) the classification of sponges into three distinct classes—namely Calcarea or Calcispongea, Hexactinellida or Hyalospongea and Demospongea—is based upon the composition and general architecture of the individual spicules; 2) classification into lower taxonomic categories is based upon the form of the sponge and the manner in which the spicules are combined to construct the skeletal structure; 3) with few exceptions, there is diversity of spicule types within individual sponge species and genera.

Spicules occur variously in living sponges as loosely attached or unattached spicules that produce a loose skeletal structure, or as strongly attached spicules that provide the sponge with a rigid skeletal structure. Upon the death of a sponge with free or loosely attached spicules, the body of the sponge disintegrates and the spicules become detached from the sponge tissue to be distributed upon the sea floor; whereas, with strongly attached spicules, the form and skeletal structure of the sponge may be preserved, although the spicules are rarely discernible.

The identification of sponge genera, or even families or orders, from the evidence of isolated spicules is, for the most part, a tenuous assignment for the following reasons: 1) isolated spicules do not show the form of the sponge or its skeletal structure, from which classification at these levels is primarily based; 2) relegation of spicules into proper sponge genera is a most difficult task due to the diversity of spicule types within individual genera. Nevertheless, it is possible to identify or at least provisionally identify some sponge genera, families, or orders, provided evidence can be obtained from unusual types of spicules or from distinctive spicule assemblages.

For purposes of biologic classification, the hexactinellid sponge spicules from the Bellefonte dolomite are assigned provisionally to *Hyalostelia* Zittel for the following reasons: 1) the modified hexactine spicules (clinopentactines) are of unusual type and show strong



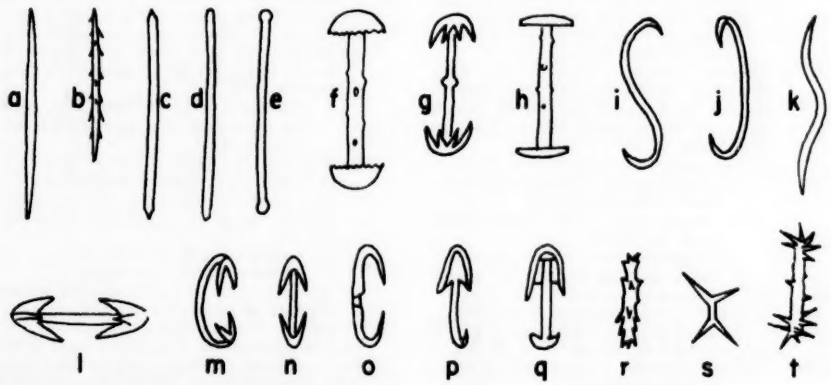

TEXT-FIG. *1—Stylose monaxons.* a, *style;* b, *tylostyle;* c, *acanthostyle;* d,e,f, various types of *clavustyles.*

resemblance in architectural form to those described and illustrated in *Hyalostelia smithii* (Young and Young) which has been considered to be the type of the genus; 2) *Hyalostelia* is not a closely defined genus and rigid restrictions have not been placed upon its characteristics. Also, in view of the fact that these spicules appear to be the first reported occurrence of siliceous sponge spicules from the Lower Ordovician of the Appalachians, a biologic classification serves to place these spicules in the paleontologic record.

The monaxon spicules of the 935-foot horizon, however, are classified morphologically but not biologically since spicules of this particular type (oxeaklosters) have been reported from many fossil sponge genera, and are present, for example, in several hundred Recent genera of Hexactinellida and Demospongea. The presence exclusively of oxeaklosters suggests that they might be assigned to the order Haplosclerida of Demospongea, but their assignment to taxonomic categories lower than order is not feasible at this stage of knowledge.

### MORPHOLOGY AND TERMINOLOGY OF SPONGE SPICULES

I. *Monaxons.*—A single axis which is either straight or curved.
   A. *Stylose monaxons.*—Extremities dissimilar. Known only as megascleres.
      1. *Styles.*—One end (strongylote) is rounded; other end (oxeote) is pointed. Text-fig. 1a.
      2. *Tylostyles.*—Broad end of style is knobbed. Text-fig. 1b.
      3. *Acanthostyles.*—Style is covered with spines. Text-fig. 1c.
      4. *Clavustyles.*—Oxeote ray terminated by a simple or scalloped disk, or a bulb-like process. Text-fig. 1d–f.
   B. *Klostose monaxons.*—Extremities similar. Primitive spindle-like spicules and their modifications. Klosters (Gr. kloster, masc. spindle) is here used as a suffix for oxeas, toxas, etc., of Groups I and II so that several terms might be grouped under a single architectural type.
      1. *Group I:* Axis straight or slightly curved. Known both as megascleres and microscleres. (In the case of microscleres, the prefix micro- is added to the following terms.)
         a. *Oxeaklosters.*—Both ends are pointed. Text-fig. 2a.



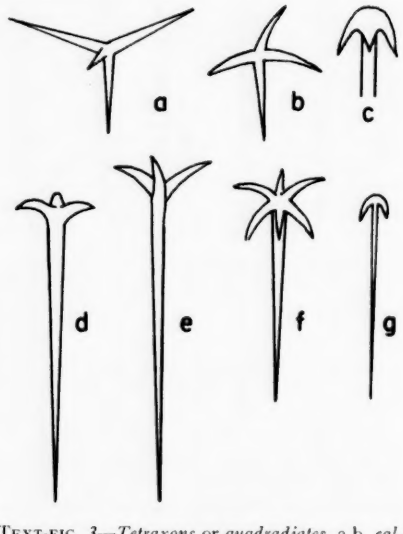

TEXT-FIG. *2—Klostose monaxons.* a. *oxeakloster;* b. *ucinakloster;* c. *tornokloster;* d. *strongylkloster;* e, *tylokloster;* f,g,h, various types of *amphidiklosters,* i,j, *sigmaklosters;* k, *toxakloster;* l,m,n,o, *isochelakloster;* p,q, *anisochelaklosters;* r, *sandiaster;* s, *plesiaster;* t, *amphiaster.*

1) *Ucinaklosters.*—Spines directed toward one end. Text-fig. 2b.
b. *Tornoklosters.*—Both ends are abruptly pointed. Text-fig. 2c.
c. *Strongylklosters.*—Both ends are rounded. Text-fig. 2d.
d. *Tyloklosters.*—Both ends are knobbed. Text-fig. 2e.
e. *Amphidisklosters.*—Both ends are terminated by umbrella-like expansions or disks. Text-fig. 2f–h.

2. *Group II:* Axis strongly curved or straight. Known only as microscleres.
a. *Sigmaklosters.*—C-shaped forms; both ends are pointed. Text-fig. 2i,j.
b. *Toxaklosters.*—Bow-shaped forms; both ends are pointed. Text-fig. 2k.
c. *Chelaklosters.*—More or less curved shaft is terminated at both ends by recurved processes, hooks, or flukes. Text-fig. 2l–q.
1) *Isochelaklosters.*—End processes are similar. Text-fig. 2l–o.
2) *Anisochelaklosters.*—End processes are dissimilar. Text-fig. 2p,q.

3. *Group III:* Axis straight, short, and spiny. Known only as microscleres and referred to as *Streptasters.*
a. *Sanidasters.*—Rod-shaped, covered with spines. Text-fig. 2r.
b. *Plesiasters.*—A few spines from a very short axis. Text-fig. 2s.
c. *Amphiasters.*—Several spines at the end of a short rod. Text-fig. 2t.
d. *Spirasters.*—Spirally twisted forms.

II. *Tetraxons* or *Quadradiates.*—Four rays, not in one plane, which radiate from a central point. May become three- or two-rayed through the loss of rays.
A. *Regular tetraxons.*
1. *Calthrops.*—Four rays approximately equal in length. Megascleres and microscleres; the latter termed *microcalthrops.* Text-fig. 3a,b.
B. *Irregular tetraxons.*—Consist of a very elongated ray (rhabdome) terminated by two or more short rays (cladi) which make up the cladome. Known only as megasteres.
1. *Tetraenes.*—Cladome of four cladi.
a. *Anatetraenes.*—Cladi directed back toward the rhabdome.
b. *Protetraenes.*—Cladi extend away from rhabdome.
c. *Plagiotetraenes.*—Cladi generally thick and are oblique or nearly horizontal to rhabdome.
2. *Triaenes.*—Cladome of three cladi.
a. *Anatriaenes.*—Cladi directed back toward rhabdome. Text-fig. 3c.
b. *Protriaenes.*—Cladi extend away from rhabdome.
c. *Plagiotriaenes.*—Cladi generally thick and are oblique or nearly horizontal to rhabdome. Text-fig. 3d,e.

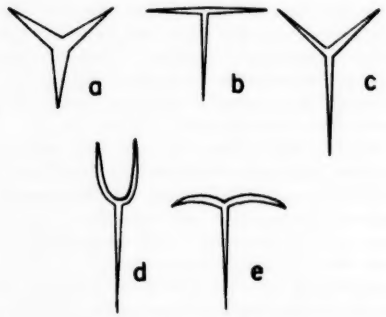



TEXT-FIG. 3—*Tetraxons* or *quadradiates.* a,b, *calthrops;* c, *anatriaene;* d,e, *plagiotriaenes;* f, *dichotriaene;* g, *anadiaene.*

d. *Orthotriaenes.*—Cladi are perpendicular to rhabdome.
e. *Dichotriaenes.*—Cladi are dichotomous or forked. Text-fig. 3f.
3. *Diaenes.*—Cladome of two cladi.
a. *Anadiaenes.*—Cladi directed back toward rhabdome. Text-fig. 3g.
b. *Prodiaenes.*—Cladi extend away from rhabdome.

III. *Triradiates* or *triactinals.*—Consist of three rays, not in one plane, which extend from a central point. Known only as megascleres.
A. *Regular triacts.*—Three rays equal in length separated by an angle of approximately 120°.
1. *Pyramidal triacts.*—Three rays form the three sides of a regular pyramid. Text-fig. 4a.
B. *Irregular or sagittal triacts.*—Paired lateral rays which differ in length from the third posterior ray and make an angle of greater or less than 120° with the posterior ray.
1. *T-shaped triacts.* Text-fig. 4b.
2. *Y-shaped triacts.* Text-fig. 4c.
3. *U-shaped* or *forked triacts.* Text-fig. 4d.
4. *Alate* or *winged triacts.* Text-fig. 4e.

IV. *Triaxons.*—Hexatinellid type spicules and their modifications. Basically consist of six rays and three axes extending at right angle from a central point. All modifications exist through the loss or reduction, branching or curving of rays. Triaxon spicules are restricted to the class Hexactinellida. Known both as megascleres and microscleres. (In the




TEXT-FIG. 4—*Triradiates* or *triactinals*. a, *pyramidal* triact; b–e, *saggital* triacts; b, *T-shaped* triact; c, *Y-shaped* triact; d, *U-shaped* or *forked* triact; e, *alate* or *winged* triact.

case of microscleres, the prefix micro- is added to the following terms.)

A. *Orthohexactines* (hexactinal triaxons).—Six rays and three axes which intersect at right angles. Text-fig. 5a,b.
   1. *Isomekactinal orthohexactines.*—Rays equal in length. Text-fig. 5b.
   2. *Anisomekactinal orthohexactines.*—Rays unequal in length.
      a. *Macrothaxonal orthohexactines.*—Long vertical axis. Text-fig. 5a.
      b. *Macrorthactinal orthohexactines.*—One ray of vertical axis is elongated.
      c. *Brachyorthactinal orthohexactines.*—One ray of the vertical axis is reduced in length.

B. *Clinohexactines* (Hexactinal pentaxons)—Transverse rays make an angle of greater or less than 90° with the vertical axis.
   1. *Isomekactinal clinohexactines.*—Rays equal in length. Text-fig. 5c.
   2. *Anisomekactinal clinohexactines.*—Rays unequal in length.
      a. *Macrorthaxonal clinohexactines.*—Vertical axis is elongated.
      b. *Macrorthactinal clinohexactines.*—One ray of the vertical axis is elongated.
      c. *Brachyorthactinal clinohexactines.*—One ray of the vertical axis is reduced in length. Text-fig. 5d.

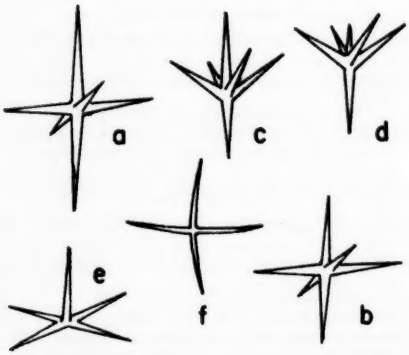
C. *Orthopentactines* (pentactinal triaxons).—Five rays and three axes which intersect at right angles. Posterior ray reduced to a small knob or is entirely absent.
   1. *Isomekactinal orthopentactines.*—Rays equal in length. Text-fig. 5e.
   2. *Macrothactinal orthopentactines.*—Vertical ray is elongated.

D. *Clinopentactines* (pentactinal pentaxons).—Five rays and five axes. Transverse rays make an acute angle with the vertical ray. Posterior ray absent or reduced to a small knob. Two planes, each containing two opposiite transverse rays and the vertical ray, intersect at right angles.
   1. *Isomekactinal clinopentactines.*—Rays equal in length.
   2. *Brachyorthactinal clinopentactines.*—Vertical or fifth ray is reduced in length. Pl. 39, figs. 8–21.

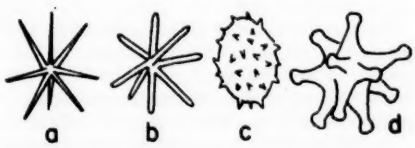
E. *Orthotetractines or stauractines.*—Four rays and two axes which intersect at right angles. Differ from tetraxons in that the four rays are in one plane. Text-fig. 5f.

V. *Polyaxons or polyactinals.*—Several rays approximately equal in length which extend from a central point. Most common as microscleres and referred to as *Euasters*.

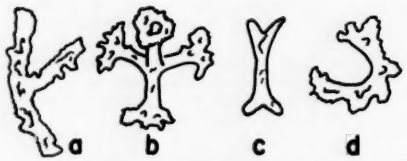
A. *Long rays with small centers.*
   1. *Oxyasters.*—Rays with pointed extremities. Text-fig. 6a.
   2. *Oxyhexasters.*—Rays terminate in a few straight branches.
   3. *Discohexasters.*—Rays terminated by disks.
   4. *Strongylasters.*—Rays with rounded extremities. Text-fig. 6b.




TEXT-FIG. 5—*Triaxons*. a, *macrorthaxonal orthohexactine;* b, *isomekactinal orthohexactine;* c, *isomekactinal clinohexactine;* d, *brachyorthactinal clinohexactine;* e, *isomekactinal orthopentactine;* f, *stauractine*.




TEXT-FIG. 6—*Polyaxons* or *polyactinals*. a, *oxyaster;* b, *strongylaster;* c, *sterraster;* d, *spheraster*.




TEXT-FIG. 7—*Desmas.* a, *tricrepid;* b, *tetracrepid;* c,d, *monocrepids.*

5. *Tylasters.*—Rays with knobbed extremities.

B. *Short rays with large centers.*

1. *Sterrasters.*—Rays reduced to minute projections. Text-fig. 6c.
2. *Spheraster.*—Rays rounded or knobbed. Text-fig. 6d.

VI. *Desmas.*—Irregularly shaped spicules which form the skeletal network of *lithistid* sponges. Formed by the deposition of silica upon a small monaxon, tetraxon, or triradiate spicule termed the *crepis.* Known only as megascleres.

A. *Monocrepid.*—Crepis is monaxon. Text-fig. 7c,d.

B. *Tetracrepid.*—Crepis is tetraxon. Text-fig. 7b.

C. *Tricrepid.*—Crepis is triradiate. Text-fig. 7a.

SYSTEMATIC DESCRIPTIONS

Phylum PORIFERA
Class HEXACTINELLIDA
Group (Order) LYSSAKINA Zittel, 1877
Family uncertain
Genus HYALOSTELIA Zittel

*Hyalostelia* Zittel, 1878, p. 178.

*Discussion.*—Hyalostelia was based by Zittel on *Hyalonema smithii,* Young and Young (1877, p. 425–431). According to Zittel's diagnosis, the spicule assemblage on which this species was based includes triaxon spicules together with stellate spicules with six to eight horizontal rays. There is some question as to whether or not Young and Young meant to include the stellate spicules in the type species. This is discussed by Reid (1957, p. 284).

Hinde (1887–1912, p. 109) emended the genus on the basis of the subsequent discovery of spicular mesh, in which separate pieces contain in some instances regular, together with modified, triaxon spicules, whereas other pieces contain stellate spicules exclusively. According to Hinde, this proves that the stellate types do not belong to the same genus as do the triaxon spicules. He, therefore, proposed that the type of the genus, *Hyalostelia smithii* (Young and Young), be based on associated regular and modified hexactinellid spicules, with the exclusion of the stellate spicules.

Hinde (1883) first referred the stellate spicules, originally included in *Hyalonema smithii* Young and Young, to *Holasterella conferta* Carter, but subsequently assigned them to *Tholiasterella* Hinde in accordance with the following information: " . . . have supplied me not only with fresh examples of detached spicules, but with fragments of the skeletal structure in which the spicules are in their original position. These fragments are built up nearly exclusively of the umbrella (stellate) spicules, and thus clearly show that we are dealing with a genus of Sponges fundamentally distinct in the character of their component spicules from those of Holasterella . . ." (Hinde, 1887–1912, p. 168–169).

*Genotype.*—*Hyalostelia smithii* (Young and Young) was considered by Hinde (1887–1912, p. 109) to be the type of the genus.

*Occurrence.*—*Hyalostelia* is known from the Cambrian Tremadoc Group, and is present in the Ordovician, Silurian, and the Lower Carboniferous, of Scotland and Ireland.

The following synonymies are after Hinde (1887–1912, p. 158).

HYALOSTELIA SMITHII
(Young and Young)

*Acanthospongia smithii* Young and Young, 1876, p. 38.
*Hyalonema parallelum* Young (non M'Coy), 1876, p. 38.
*Acanthospongia smithii* Carter, 1877, p. 176.
*Hyalonema smithii* (in part) Young and Young, 1877, p. 426, pl. 14, figs. 1–3,5–12,14–17, pl. 15, fig. 30.
*Acanthospongia smithii* Zittel, 1877, p. 60, pls. 1–4.
*Hyalonema parallela* R. Ethridge, Jr., 1878, p. 119.
*Hyalonema smithii* (in part) Carter, 1878, p. 129, pl. 9, figs. 1–9,12,13.
*Hyalostelia smithii* Zittel, 1878, p. 185.
*Hyalonema smithii* Nicholson, 1879, p. 145.
*Acanthospongia smithii* F. Roemer, 1880, p. 317.
*Hyalostelia smithii* Hinde, 1883, p. 150, pl. 32, figs. 1,1a–1g.

*Partial description.*—"the dermal layer of the sponge consists of relatively large hex-

actinellid spicules in which the distal ray of the vertical axis is reduced to a small rounded knob or process, or is altogether wanting, whilst the transverse rays are of unusual length, and incline downwards from the central node. These spicules are disposed so that the transverse rays overlap each other, and thus form quadrate interspaces which are partially filled by smaller spicules." (Hinde, 1887–1912, p. 158, pl. 6, figs. 1,2, esp. 1a.)

*Relationships.*—De Laubenfels (1955, p. 93) assigns *Hyalostelia* Zittel and *Tholiasterella* Hinde to the family Astraeospongiidae, order Heteractinida, which is in disagreement with Hinde's diagnosis; the two genera cannot occupy the same taxonomic position. This is also discussed by Reid (1957, p. 284).

*Occurrence.*—*Hyalostelia smithii* (Young and Young) is widely distributed in the Lower Carboniferous of Scotland and Ireland.

HYALOSTELIA CLINOPENTACTINOIDES
Butler, n. sp.
Pl. 39, figs. 8–21

*Description.*—Skeletal structure and form of sponge unknown. The assemblage of loose but associated fossil spicules is composed of about 95 percent clinopentactine spicules, upon which the species is based, and about 5 percent orthohexactine, clinohexactine, and orthopentactine spicules which, in view of the association, are assumed to belong to the same species. Spicules siliceous, with rough crystalline surfaces; silica is chalcedony as determined by the optical properties of several rays observed in this section; all transitions exist from spicules which show no replacement by pyrite to several which have been almost entirely replaced.

Clinopentactine spicules have four transverse rays and a fifth, vertical ray; each transverse ray makes an acute angle with the fifth or vertical ray (pl. 39, fig. 10), averaging about 68° as determined by 150 measurements; this angle varies from 77° to 62° for all measurements, whereas variation of this angle in rays of one specimen is generally less than 6° maximum. Vertical ray, in all cases, shorter in length and smaller in diameter than transverse rays. Angle between adjacent transverse rays is 90° (pl. 39, fig. 12). Planes formed by vertical ray and two opposite transverse rays intersect at right angles.

Individual rays circular in cross section, generally long and slender, and gradually taper to a point distally. Lengths of transverse rays commonly about 1.5 to 2.0 mm. with observed maximum and minimum lengths of 4.0 and 0.25 mm., respectively. Therefore, average transverse dimensions (distance between distal portions of opposing transverse rays, pl. 39, fig. 10) of reconstructed spicules is about 3.5 mm. and maximum and minimum transverse dimensions are about 7.5 and 0.45 mm., respectively; transverse dimensions are only approximations as majority of rays are broken and have blunt extremities. Diameter of individual rays, measured at maximum thickness of ray, commonly about 0.15 to 0.20 mm. with observed maximum and minimum diameters of 0.33 and 0.05 mm., respectively.

Spicules are very large in comparison to the size range for megascleres given by de Laubenfels (1955, p. 27) which is as follows: "Most megascleres exceed 3 microns in diameter, many are 10 microns, and some are more than 30 microns. Megascleres mostly are more than 100 microns long, but many large forms are more than 300 microns in length, and a few attain greatest length of 1,000 microns." In comparison, the average transverse dimension of the spicules described above is about four times that of the largest given by de Laubenfels.

The associated orthohexactine, clinohexactine, and orthopentactine spicules have rays which generally are shorter in length and smaller in diameter than rays of clinopentactine spicules; diameter of individual rays, measured at maximum thickness of ray, commonly about 0.12 to 0.15 mm. with maximum and minimum diameters of 0.25 and 0.09 mm., respectively. Lengths of individual rays undeterminable. Several spicules show rays which are rounded distally (pl. 29, figs. 1,2,5) while most appear to gradually taper to a point distally. Orthohexactine spicules have six rays and three axes which intersect at right angles; rays generally equal in length. Clinohexactine spicules have six rays and four to five axes; either or both of the pairs of opposing transverse rays make an angle other than 90° with the vertical

axis; acute angle commonly about 80° to 85°; generally, rays are unequal in length. Orthopentactine spicules have five rays and three axes which intersect at right angles; distal ray reduced to a small knob or process (pl. 39, figs. 6,7).

*Relationships.*—*Hyalostelia clinopentactinoides* is characterized by the almost exclusive presence, at least in the current collections, of modified hexactinellid (clinopentactine) spicules which, in architectural form, strongly resemble those of *H. smithii* (Young and Young). *H. clinopentactinoides* differs from *H. smithii* in that the anchorate spicules, such as those included in *H. smithii*, have not been observed in the spicule assemblage of *H. clinopentactinoides*, and also, the hexactine and orthopentactine spicules, which are common to the assemblage of *H. smithii*, are rare in *H. clinopentactinoides*. The rare presence of hexactine and orthopentactine spicules may prove to be characteristic of *H. clinopentactinoides*.

*Range.*—Lower Ordovician (Beekmantown).

*Occurrence.*—The clinopentactine spicules placed in *Hyalostelia clinopentactinoides* are extraordinarily abundant 940 feet stratigraphically below the top of the Bellefonte dolomite near Union Furnace, Huntingdon County, Pennsylvania, and are not known as yet from other localities of the Bellefonte formation. The associated spicule types are rare at the 940-foot horizon and have not been observed elsewhere in the formation.

## MORPHOLOGIC DESCRIPTIONS

### Oxeaklosters

Pl. 39, figs. 22–25

*Description.*—Skeletal structure and form of sponge unknown. Spicule assemblage is composed of 100 percent oxeaklosters.

Spicules siliceous, with rough crystalline surfaces; silica is chalcedony; several spicules show minor replacement by pyrite, although majority show no replacement.

Spicules straight, although some slightly curved; spicules circular in cross section, slender, and gradually taper to a point at both extremities; average length of spicules commonly about 0.5 mm. with observed maximum and minimum lengths of 1.0 and 0.25 mm., respectively. Average diameter commonly about 0.35 mm. with observed maximum and minimum diameters of 0.065 and 0.025 mm., respectively.

*Range.*—Lower Ordovician (Beekmantown).

*Occurrence.*—Oxeaklosters common 935 feet stratigraphically below the top of the Bellefonte dolomite near Union Furnace, Huntingdon County, Pennsylvania, and are not known from other horizons or localities of the Bellefonte formation.

## ECOLOGIC CONSIDERATIONS

According to Hyman (1940, p. 325,332). Recent hexactinellid sponges (p. 325) are exclusively marine, and (p. 332) are cosmopolitan in distribution, ranging from tropical to polar waters, although they are more common in tropical latitudes. They are considered to be deep-sea animals seldom found above 100 meters; though most common at depths of 500 to 1,000 meters, they extend to depths of about 5,000 meters. Oakley (1937) is of the opinion that the exclusive presence of hexactinellid sponges gives little information about depth, although its association with other types of sponges may provide helpful data. He also states that the hexactinellids seem to be particularly associated with muddy bottoms, cold water conditions, and quiet water or steadily flowing currents.

With respect to monaxonid in contrast to hexactinellid sponges, Hyman (1940, p. 343) states that modern representatives are relatively shallow-water animals, being found mostly in in-shore and shallow waters down to about 50 meters, although some are present to 5,000 or 6,000 meters. Chilingar (1958, p. 216) suggests that the presence of monaxonid sponge spicules in deep-sea sediments, especially in the Far Eastern seas with strong tidal currents, might be explained by transportation of sponges from topographic highs into deeper warters. As stated by Shrock and Twenhofel (1953, p. 94), all Porifera are marine with the exception of a small group of monaxonid sponges constituting the fresh-water family, Spongillidae. De Laubenfels (1955, p. 37) gives the range of the Spongillidae from Jurassic to Recent.

Chilingar (1958, p. 218), in a review of Soviet literature, presents the following

summarization of the findings of Soviet marine geologists as given by Petelin (1954):

"1. Siliceous-sponge deposits, composed chiefly of siliceous sponge spicules, are forming on the sea floor today.

"2. Typical siliceous-sponge deposits form within the limits of the continental shelf and slope up to depths of 400 meters. The major portion of these deposits is composed of Tetractinellid sponge spicules with some admixture of Monactinellid spicules.

"Sediments with high content of deep-water Hexactinellid sponge spicules are encountered at depths greater than 400 meters.

"3. The formation of siliceous-sponge deposits is associated with mass development of siliceous sponges in relatively cold, turbulent waters having normal salinity.

"4. Tetractinellid and Monactinellid sponges grow in waters of high oxygen saturation, whereas Hexactinellid sponges do not require high oxygen saturation. However, this factor appears to be of secondary importance.

"5. Mass development of sponges occurs in regions with active volcanic activity, such as Far Eastern seas, and in areas without volcanic activity (Bering Sea). Thus, the presence of volcanic activity as a source of silica in sea water is not indispensable for the mass development of sponges.

"6. In areas with mass development of sponges, the amount of silica in sea water varies within wide limits. Although the waters of Bering Sea contain considerably less silica than Far Eastern waters, sponges are more abundant in Bering Sea. Therefore, a high concentration of silica in sea water is not a controlling factor."

Chilingar (1958, p. 218) also gives the following information: "Teodorovich (1954), who subdivided the sedimentary geochemical environments on the basis of Eh and pH, assigns weakly oxidizing and oxidizing zones to sediments containing sponge spicules, with pH ranges of 5.0 to 8.0 for weakly oxidizing and 6.6 to 7.2 for oxidizing zones."

From the known environmental relationships of Recent sponges, it is considered that *Hyalostelia clinopentactinoides* as well as the monaxonid sponges of the Bellefonte dolomite inhabited waters which were marine and continuously aerated. The depth at which these sponges lived is much less clear due to the wide range of depth distribution of modern examples of the two groups. It is likely, however, that the depth of water, which these two groups inhabited, did not differ by more than a few or a few tens of meters as evidenced by the regularity of bedding and the basic sedimentary framework of the lower portion of the Bellefonte formation. Whether *H. clinopentactinoides* inhabited deep-sea water or lived on a bottom of ooze is questionable because, as stated by de Laubenfels (1936), sponges living in either of these two environments regularly have large "rooting tufts" which have not been observed as yet in this species. In spite of the absence of detrital and clastic material in the dolomite, which is associated with *H. clinopentactinoides*, current action is indicated by the relatively uniform distribution of the spicules along a very thin band, as well as the fact that sponges required aerated water.

The monaxonid spicules, which occur five feet above the hexactinellid horizon, are associated with an abundance of grains of quartz silt and fine sand, as well as rounded chert grains of medium- to coarse-sand size. The occurrence perhaps represents a shallow depth of water and a sea floor which was disturbed by current or wave action.

[*Please turn page for* PLATE 39]

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MANUSCRIPT RECEIVED JULY 21, 1959

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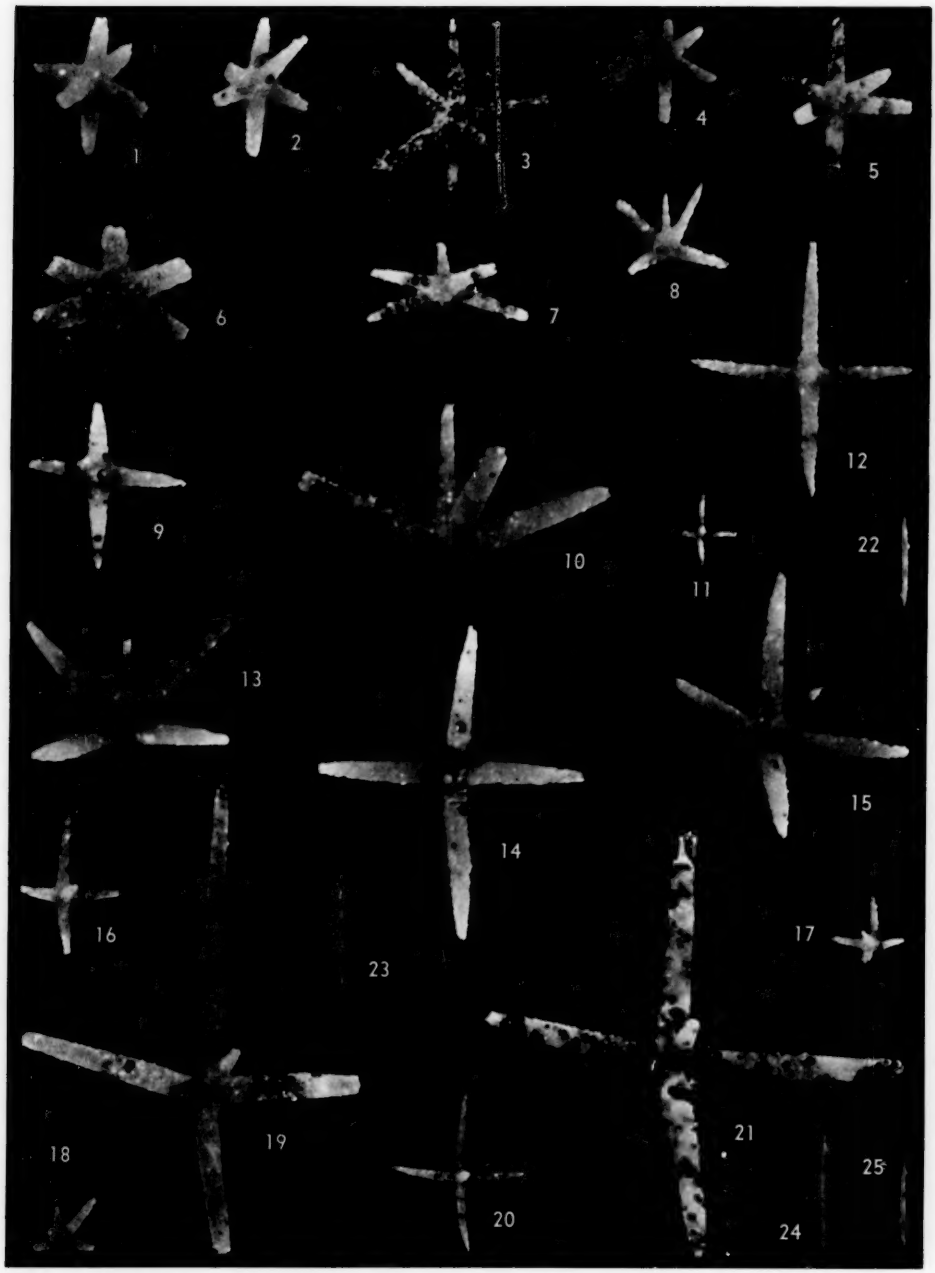
EXPLANATION OF PLATE 39

All figures, except figs. 22–25, about ×21

FIGS. *1–7*—*Hyalostelia clinopentactinoides* Butler, n. sp. Oblique views of hexactine and orthopentactine spicules. Orientation of vertical axis of hexactine spicules is questionable. *1–3*, Clinohexactine spicules; rays do not intersect at right angles. *1,2*, A few rays are rounded distally. *3*, Specimen almost entirely replaced by pyrite; rays are pointed distally. *4,5*, Orthohexactine spicules; rays intersect at right angles. *6,7*, Orthopentactine spicules; rays intersect at right angles; posterior of sixth ray is reduced to a small projection or process. Near Union Furnace, Pennsylvania, 940 feet below top of Bellefonte dolomite.

*8–21*—*Hyalostelia clinopentactinoides* Butler, n. sp. Views of clinopentactine spicules upon which the species is based. *8,13,15–21*, Oblique views. *9,11,12,14*, Vertical views. *9*, Specimen with short, stubby rays. *10*, Lateral view showing acute angles between the transverse rays and the vertical ray. *13–15*, Same specimen in different orientations. *19,21*, Very large spicules with very long, thin, transverse rays. *21*, Shows much replacement by pyrite. Near Union Furnace, Pennsylvania, 940 feet below top of Bellefonte dolomite.

*22–25*—Oxeaklosters. Specimens about ×25. Near Union Furnace, Pennsylvania, 935 feet below top of Bellefonte dolomite.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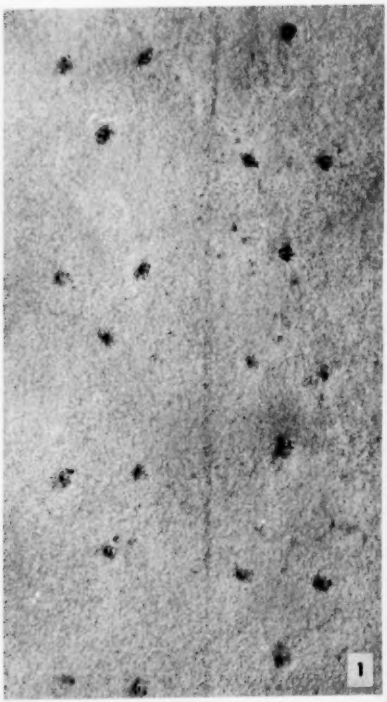
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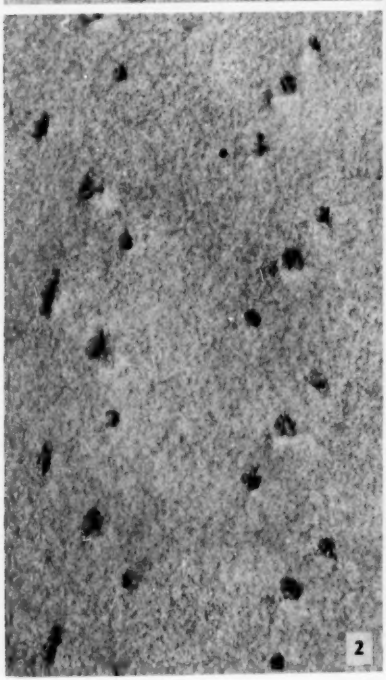
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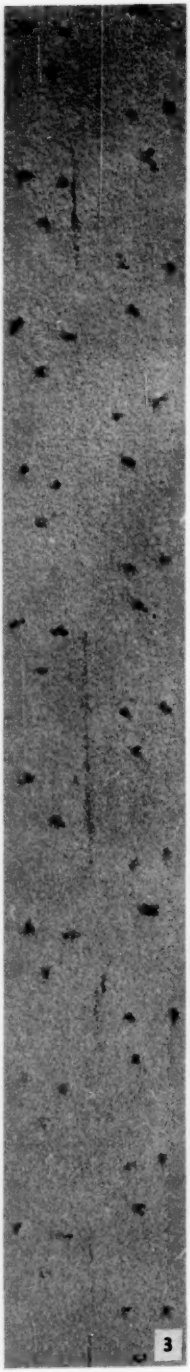
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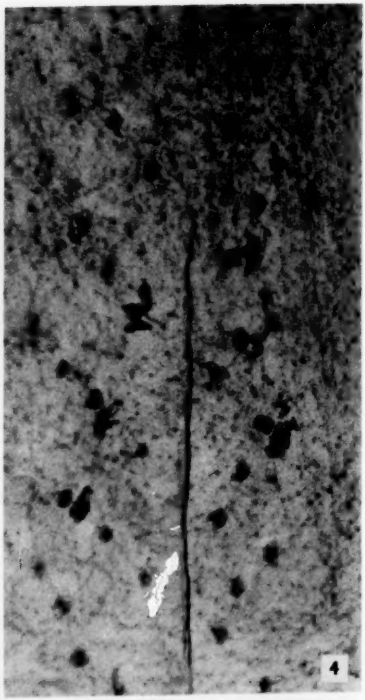
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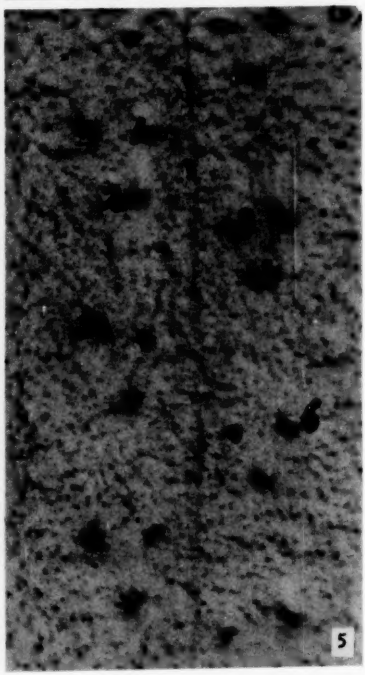
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JOURNAL OF PALEONTOLOGY, V. 35, NO. 1, P. 201–202, PL. 40, JANUARY, 1961

# A NEW SPECIES OF *PALAEOHELCURA* GILMORE FROM THE PERMIAN OF NORTHERN ARIZONA

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ABSTRACT—A new species of *Palaeohelcura*, from the Coconino sandstone (Permian) of Northern Arizona, is described as differing from *Palaeohelcura tridactyla* Gilmore in the pattern of foot impressions.

## INTRODUCTION

THE commonest invertebrate track in the Coconino sandstone is that of *Palaeohelcura tridactyla* Gilmore (1926). In this track three feet impress in a definite pattern on each side of a tail drag, in usually straight lines inclined forward at an angle which varies from about 25° to 35° with the direction of travel. The "stride" varies from 14 to 18 mm., and the width of the track from 17 to 22 mm., these figures being derived from measurements of a number of specimens in the collection of the Museum of Northern Arizona.

This track has been referred (Brady, 1947) to a small scorpion.

Recently, six somewhat similar tracks have been collected, five from the Coconino sandstone in the neighborhood of Ash Fork, and one from the DeChelly sandstone in the Navajo Reservation, which show a foot pattern markedly different from the above, and is here described as that of a new species.

The pattern appears as a series of triangular groups arranged regularly on each side of a tail drag, the latter being sometimes very faint or occasionally absent, as is the case with *Palaeohelcura tridactyla*. The specific name *dunbari* is suggested in gratitude to R. E. Dunbar of Ash Fork, who donated to the Museum the specimens selected as types.

In this form the ratio of "pace" to width of track is on the average 87%, compared to 73% in specimens of *Palaeohelcura tridactyla*, although the two species appear to represent the tracks of arthropods of about the same size and genus. In the following comments and suggestions about the probable order of movements of the legs, it would seem probable that the legs of the new species were somewhat longer than those of Gilmore's species of the same genus. The accompanying illustrations show clearly the marked difference between the two forms of tracks, and it should be noted that the direction of travel is usually quite clear from the displacement of the sand at the river of the foot impressions.

In attempted observations of the order of placement of the feet of recent scorpions in normal motion, it seemed that the front pair did not impress, and that the second, third and fourth feet on each side impressed in that order, although unfortunately a high speed movie camera and a live scorpion were not available at the same time. In was noted, however, that the recent scorpion,

## EXPLANATION OF PLATE 40

In all figures the tracks proceeded from the bottom to the top of the illustration.

FIGS. *1,3,5*—*Palaeohelcura dunbari*, n. sp. *1*, holotype, MNA G2-3295; part of track from a slab 62 cm. long with a straight track along its entire length; Coconino sandstone, quarry north of Ash Fork; ×4¼. *3*, paratype, MNA G-27089; part of a track from a slab 70 cm. long; ×⅘. *5*, another part of MNA G2-7089, with numbers to indicate the apparent order of placement of the feet; ×1.2.

*2,4*—*Palaeohelcura tridactyla* Gilmore. *2*, MNA IG2-2087; Coconino sandstone, north of Ash Fork; ×1½. *4*, part of the same specimen with numbers to indicate the apparent order of placement of the feet; ×1.2.

*Centruroides*, when somewhat torpid, left tracks which showed impressions of all eight feet, but when active made tracks very like those of *Palaeohelcura tridactyla*.

The illustrations of crayon rubbings of natural casts of the two types of *Palaeohelcura* tracks offer a suggestion of the order of foot placement.

ARTHROPODA
?SCORPIONIDA
PALAEOHELCURA DUNBARI n. sp.
Pl. 40, figs. 1,3,5

*Description.*—A track formed of impressions of three feet only on each side, in regular triangular groups, with a median tail drag usually present. The track is often remarkably straight for considerable distances, and varies in width from 24 to 29 mm., resembling in general the track of *Palaeohelcura tridactyla* Gilmore except for the pattern of the foot impressions.

*Occurrence.*—Coconino sandstone and De-Chelly sandstone of Northern Arizona.

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# LATE TERTIARY BIOGEOGRAPHY OF HORSES IN THE NORTHERN GREAT BASIN

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ABSTRACT—The late appearance of the single toed horse, *Pliohippus*, in the Northern Great Basin provides an opportunity for study of its environmental requirements in contrast to those of the three toed horse, *Hipparion*, which occupied the region earlier and contemporaneously. Many characteristics of vegetational change in the Northern Great Basin of the late Tertiary coincide with the historical biogeography of these and other horses in this region. This conclusion leads to possible answers to related problems of migration, homotaxis, community change, and morphology in equids.

## INTRODUCTION

AT LEAST seven genera of grazing horses, comprising members of two closely related but distinct phyletic lines are recognized in the Late Tertiary of North America. They vary in morphology from one-toed to three-toed forms, and from delicate almost antelope-like forms to heavy-limbed types comparable to a dray horse. They all have high crowned teeth, and their appendicular skeletons indicate many adaptations for speed in running. Although these horses are all grazers, such a varied morphology suggests that they may have found their food in somewhat different habitats. In regions where all these forms existed contemporaneously throughout their history it is difficult to determine any preferences to particular habitats. If, however, both phyletic lines are not always present in a region then the possibility of recognizing habitat preferences is much better.

In the Northern Great Basin single-toed grazers appear much later than three-toed grazers, although they are contemporaries in other regions. Study of the changing vegetational history of this province not only provides an explanation for this distribution, but indicates the nature of the differences in the habitats preferred by each of the groups of horses. This evidence in turn points to the significance of some of the morphological differences between them. In addition, the conclusions reached imply answers to problems involving migration, homotaxis, community change, and a number of other problems in which these mammals played an important part.

FIG. 1—The Great Basin of Western North America.

## ACKNOWLEDGMENTS

Collections of the Museum of Paleontology of the University of California, Berkeley and the California Institute of Technology were of great aid in the preparation of this study. I am therefore grateful to the curators and collectors of these specimens. I am also indebted to Drs. R. W. Chaney and D. I. Axelrod who read the manuscript and offered constructive criticism and helpful advice. They cannot be responsible for any errors of interpretation of the paleobotanical data which I may have made in spite of their efforts.

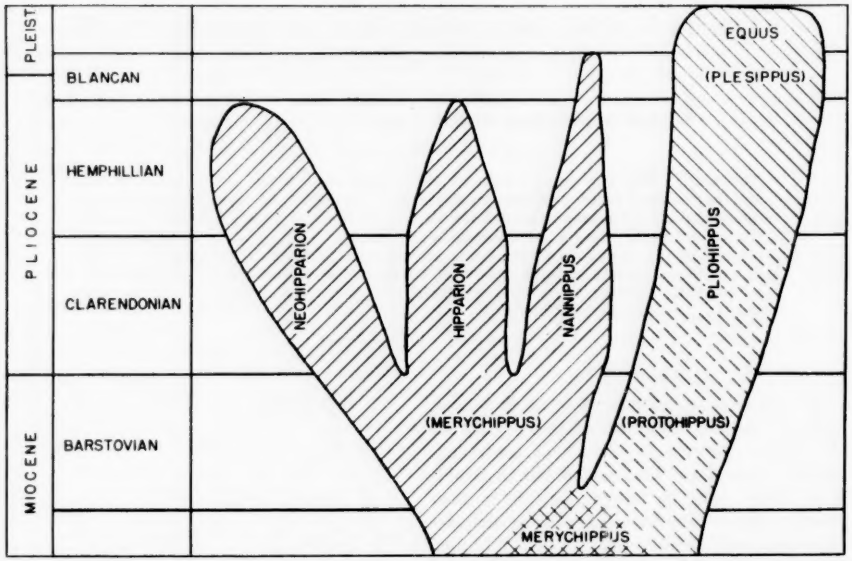


FIG. 2—Phylogenetic relationships of Late Tertiary grazing horses. Broken cross-hatching indicates portion of the history of *Merychippus* (*Protohippus*) and early *Pliohippus* missing in the Northern Great Basin.

This study is an outgrowth of work supported by the National Science Foundation.

## DISTRIBUTION OF GRAZING HORSES

In any distribution study, whether involving recent or fossil organisms, the establishment of areas of non-occurrence is the most difficult task. This difficulty is more evident in fossil organisms due to the greater possibility of missing occurrences. In the present instance the fact that horses are often abundant in samples of fossil faunas makes it less likely that an entire subgroup could be overlooked in a large region from which many samples are available. The possibility that these samples universally represent only one environmental situation, thus not yielding particular groups of mammals living in other situations, is recognized. However, it is often the case that more than one environmental situation is represented in a sample (Shotwell 1955, 1958A). Members of other environments are presumably present by chance. Mammals of large population size are thus seen as sporatic representatives in samples of environmental situations foreign to them.

Each of the maps (text-figs. 3–6) includes the geographic occurrence of faunas containing one or both groups of horses. Cross hatching represents the probable general distribution of each of the groups of horses concerned based on the known occurrences or apparent absences of each group. Several regions of no information are left blank. The blank region along the Pacific Coast has not produced any Late Tertiary terrestrial faunas; the exposed rocks in this province are largely pre-Tertiary and marine Tertiary. The other large region left blank is that of the Rocky Mountains. The distributions are not extended into or over this region unless definite information is available.

*Pliohippus*, a single-toed grazing horse, occurs first in the Clarendonian (early Pliocene) faunas of most regions of western North America. In faunas of the Northern Great Basin, however, *Pliohippus* is not recorded until the Hemphillian (mid Pliocene)

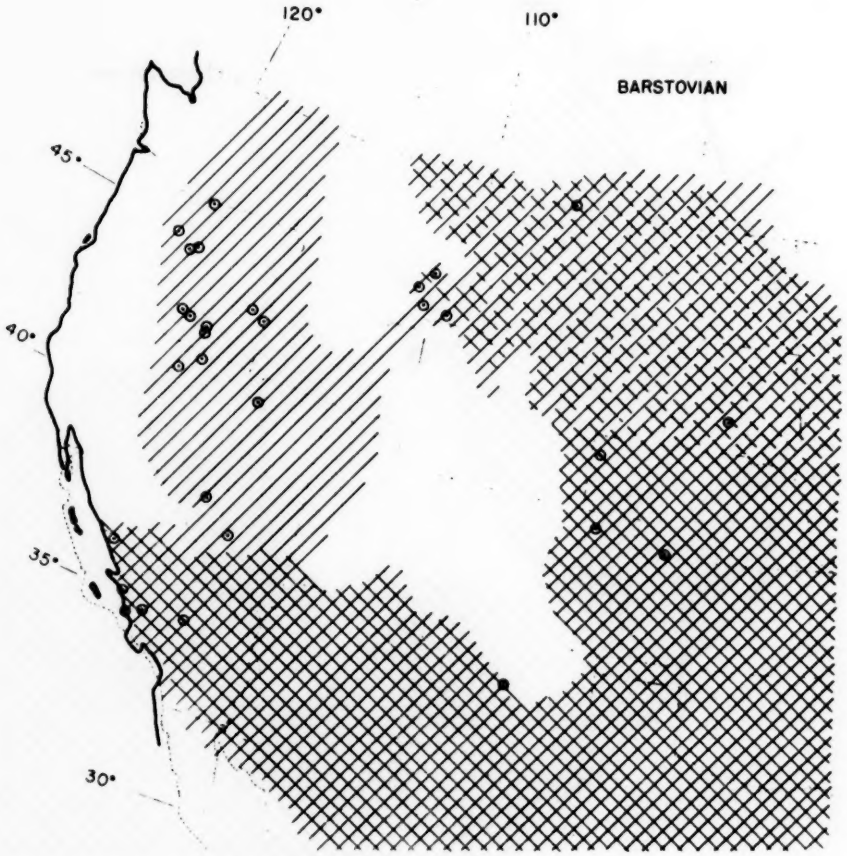


FIG. 3—Distribution of *M.* (*Merychippus*) and *M.* (*Protohippus*) in Western North America in the Barstovian. Points on the Map indicate localities providing items of evidence. Cross-hatching is a generalization of the distribution of each subgenus. /// *M.* (*Merychippus*), \\\ *M.* (*Protohippus*).

though other grazing horses (*Hipparion*, three-toed) are present here in the Clarendonian; they also occur in Hemphillian faunas. These two genera diverged from the common genus *Merychippus* of the *Barstovian* (late Miocene). Still earlier diversifications into these lines can be seen in the genus *Merychippus* which has led to the establishment of subgenera within *Merychippus*. These subgenera *M* (*Merychippus*) and *M* (*Protohippus*) gave rise to *Hipparion* and *Pliohippus* respectively. These phylogenetic relationships including the relationship of other so-called hipparion horses (*Neohipparion* and *Nannippus*) are shown in text-figure 2.

The distribution of the two subgenera of *Merychippus* which gave rise to *Hipparion* and *Pliohippus* provides a good beginning point in the study of the migration of *Pliohippus* into the Great Basin. Text-figure 3 is a map of the distribution of these two

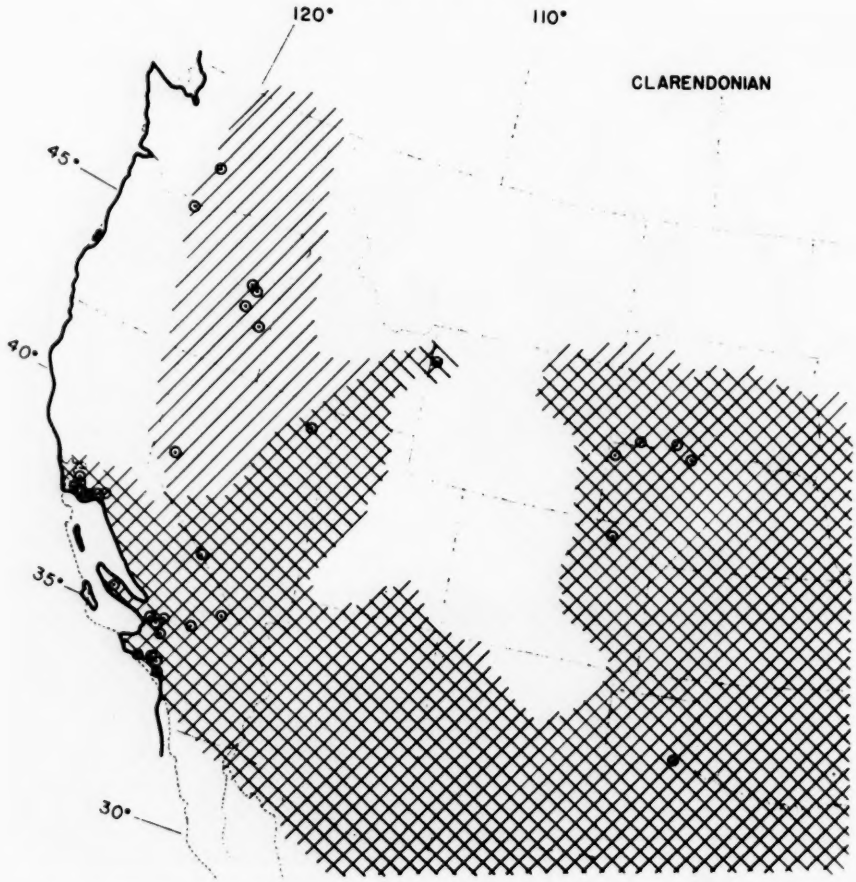


FIG. 4—Distribution of *Pliohippus* and hipparion horses in Western North America in the Clarendonian. /// hipparion horses, \\\ *Pliohippus*.

groups of horses in the Barstovian (late Miocene) of Western North America.

*M.* (*Protohippus*) which includes the ancestors of *Pliohippus* is not known from the Great Basin although Wallace (1932) identified a specimen of *M.* (*Protohippus*) *campestris* from the Beatty Butte fauna of southeastern Oregon. Downs (1956) has shown that this specimen is a well worn dentition of *M.* (*Merychippus*) *seversus*. In most other regions of North America shown on the map both subgenera of *Merychippus* occur, often in the same faunas. *M.* (*Merychippus*) from which the hipparion horses are derived is found throughout the Great Basin in the Barstovian.

By the Clarendonian *Hipparion* and *Pliohippus* have appeared, replacing their ancestors in the subgenera of *Merychippus*. In the Great Basin *Hipparion* had a similar distribution as the earlier *M.* (*Merychippus*). *Pliohippus*, however, has expanded from the distribution of *M.* (*Protohippus*) into the southern Great Basin. See map (text-figure 4).

In the Hemphillian *Pliohippus* extended

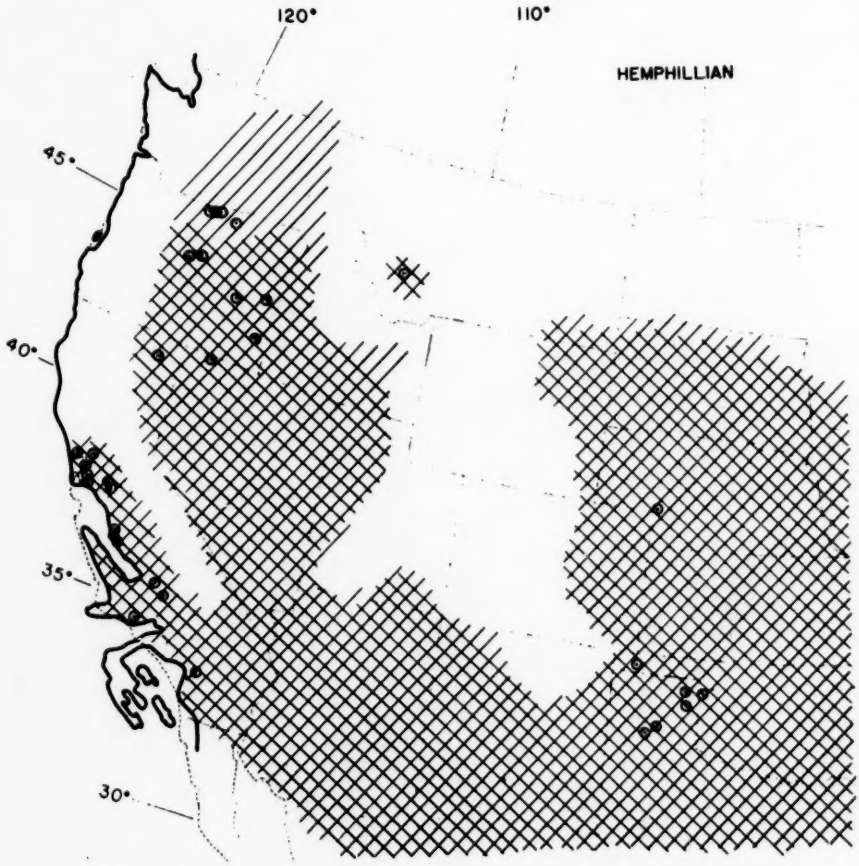


FIG. 5—Distribution of *Pliohippus* and hipparion horses in Western North America in the Hemphillian. /// hipparion horses, \\\ *Pliohippus*.

its range into the Northern Great Basin, but was apparently absent from the Columbia River Basin to the north. Re-examination of tooth fragments from the Westend Blowout fauna along the Columbia River shows them to be of a hipparion horse, and not referable to *Pliohippus*, as earlier reported (Shotwell 1958A), see text-figure 5.

*Pliohippus* is succeeded in the Blancan (late Pliocene) by *Equus* (*Plessippus*), which is known from nearly every locality of this age in western North America. Hipparion horses are represented only by *Nannippus phlegon*, a highly specialized form in the Southwest (see text-fig. 6).

We may summarize these events as follows: The direct ancestors of *Pliohippus* did not live in the Great Basin, the ancestors of *Hipparion* were common there. *Pliohippus* first appeared in the southern Great Basin in the Clarendonian and expanded into the Northern Great Basin in the Hemphillian. At the end of the Hemphillian, *Pliohippus* was replaced by another single-toed horse, *Equus*. *Hipparion* horses became extinct in the Great Basin after the Hemphillian.

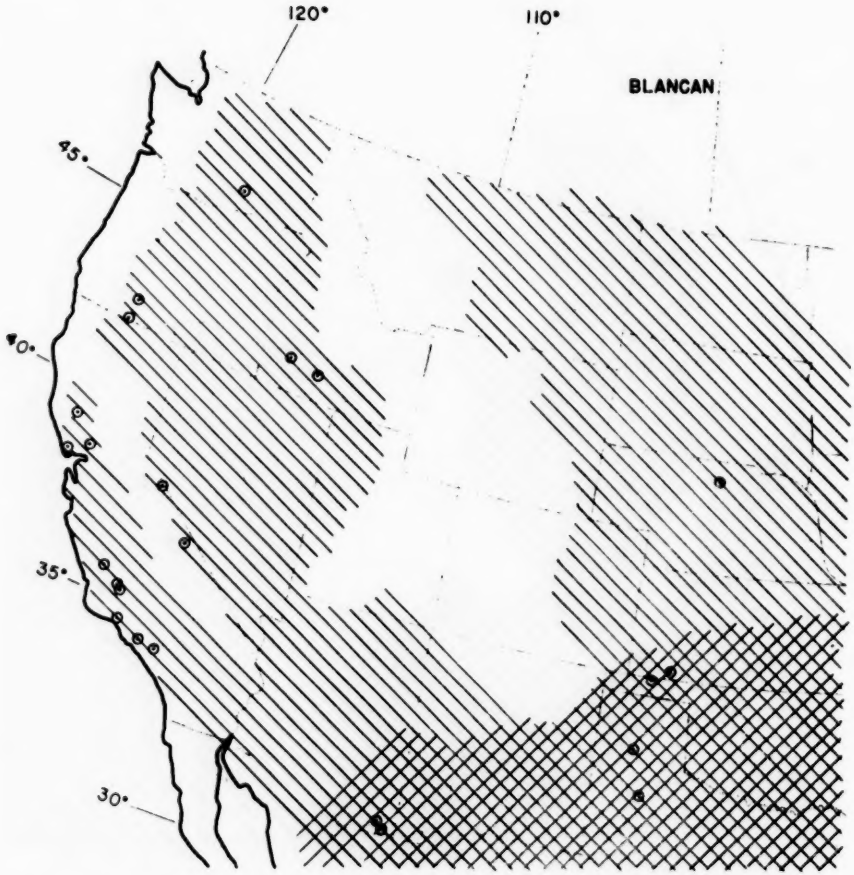


FIG. 6—Distribution of *Equus* (*Plesippus*) and hipparion horses (*Nannippus phlegon*) in Western North America in the Blancan. /// *Nannippus phlegon*, \\\ *Equus* (*Plesippus*).

## VEGETATION AS A FACTOR IN HORSE DISTRIBUTION

The absence of *M.* (*Protohippus*) and the delayed appearance of *Pliohippus* in the Great Basin suggests that conditions there must have been significantly different than those elsewhere in North America where such absences and delays did not occur. A major factor in the distribution of mammals is vegetation. Other than its role as a food base and cover for mammals, vegetation especially in the study of fossil mammals, is important because of its reflection of climate and to a lesser degree topography. Vegetation may thus reflect a number of important factors in the distribution of mammals directly or indirectly. A review of the vegetation of the Late Tertiary in the Great Basin may be expected to shed much light on the anomalous distribution of *Pliohippus* and its immediate ancestors in this region.

The vegetation of the Great Basin is known to have changed greatly in the Late Tertiary. Two Geofloras, the Arcto-Tertiary

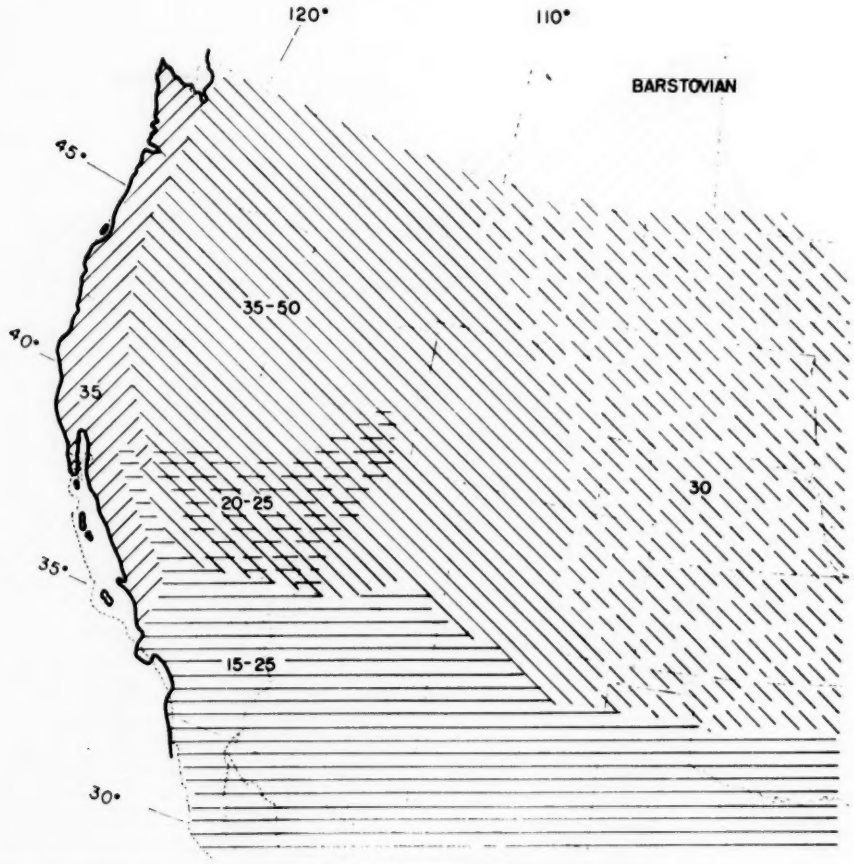


FIG. 7—Distribution of Geofloras in Western North America. Numbers indicate estimated yearly rainfall. /// Coastal aspects of Arcto-Tertiary. \\\ Mesic continental aspect of Arcto-Tertiary. ... Dry aspects Arcto Tertiary. ≡ Madro-Tertiary. ≡ Madro-Tertiary influence.

and Madro-Tertiary, occupied the major part of western North America in this time. They take their names from their early Tertiary geographic origins. The Arcto-Tertiary Geoflora included hardwood deciduous and broad-leafed evergreen woodlands as well as coniferous forests. In its drier aspects plains grasslands are present. The Madro-Tertiary Geoflora contained chiefly small-leafed, drought resistant and drought deciduous sclerophylls and microphylls. These are included in iive oak and conifer woodland, chapparal, arid subtropical scrub, coastal sage and plains grassland. For a more inclusive description of the nature of these floras see Chaney (1944, 1959), Axelrod (1950), or Axelrod (1958). The distribution of these geofloras as dominants may be mapped by generalizing the results described principally in Chaney and Elias (1936), Chaney (1944), and Axelrod (1939, 1948, 1956). Text-figs. 7–9 are maps of the distribution of these two floras at different times in the Later Tertiary in

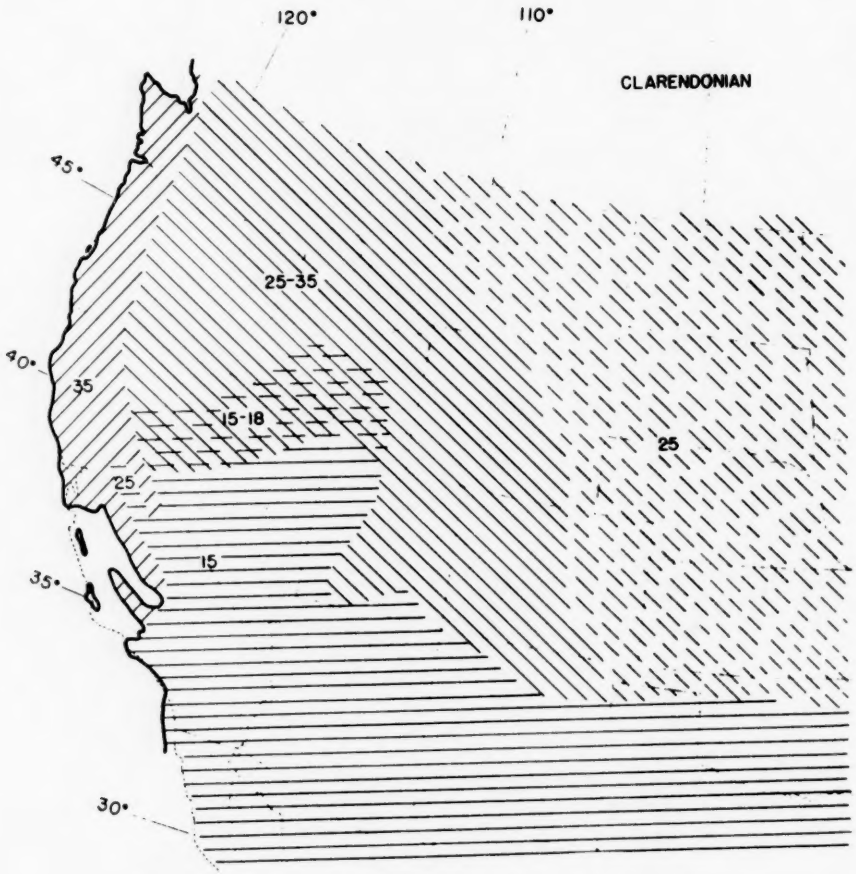


FIG. 8—Distribution of Geofloras in Western North America in the Clarendonian. Legend same as figure 7.

Western North America. The changing coastline is adapted from Corey (1954) and Taliaferro (1951).

The maps show that the areas of dominance of the Madro-Tertiary and Arcto-Tertiary Geofloras changed little in the Late Tertiary except within the Great Basin. Earlier in the Tertiary the Arcto-Tertiary Geoflora had moved southward whereas the Madro-Tertiary appears to have radiated from a center in Southwestern North America. In the sequence demonstrated in the maps only distribution changes in the Great Basin are significant. However, it will be noted from the precipitation figures that a general drying occurred in all of western North America. This is most evident in the Great Basin in the Hemphillian. This effect was continued into the Pleistocene as the mountains to the west continued to become higher by accumulation of volcanics and by tectonic activity. The present semi-arid aspect of the Great Basin was established in the Hemphillian (Axelrod 1948, 1950). It will also be noted from the maps that there are two related gradients from south to

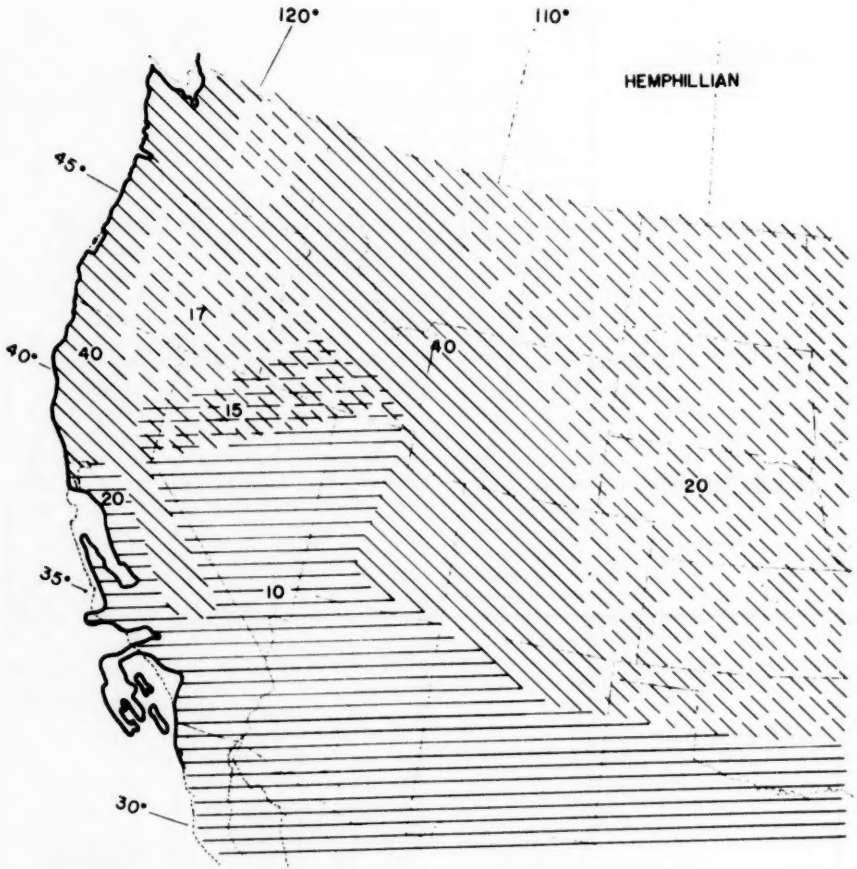


FIG. 9—Distribution of Geofloras in Western North America in the Hemphillian. Legend same as figure 7.

north in the Great Basin through the Late Tertiary. One of these is rainfall, with the Northern Great Basin always the more mesic and the southern part the driest. The other is a gradient of Geoflora affinities. The region to the south is dominated by the Madro-Tertiary Geoflora, that to the north by the Arcto-Tertiary Geoflora. The area between is in some parts ecotonal, but for the most part a mixture of areas of dominance of the two Geofloras dependent on local exposure and topography. In the Barstovian the mesic Arcto-Tertiary elements extend throughout the Great Basin but are mixed with local dominant areas of the drier Madro-Tertiary in the south. By the Clarendonian the Madro-Tertiary Geoflora has extended northward and the hardwood-deciduous and conifer forests of the Arcto-Tertiary has largely been displaced from the central Great Basin except for more mesic local areas such as higher elevations and stream borders. As this trend continued into the Hemphillian the Madro-Tertiary influence did not move much farther northward probably due to the cold winters.

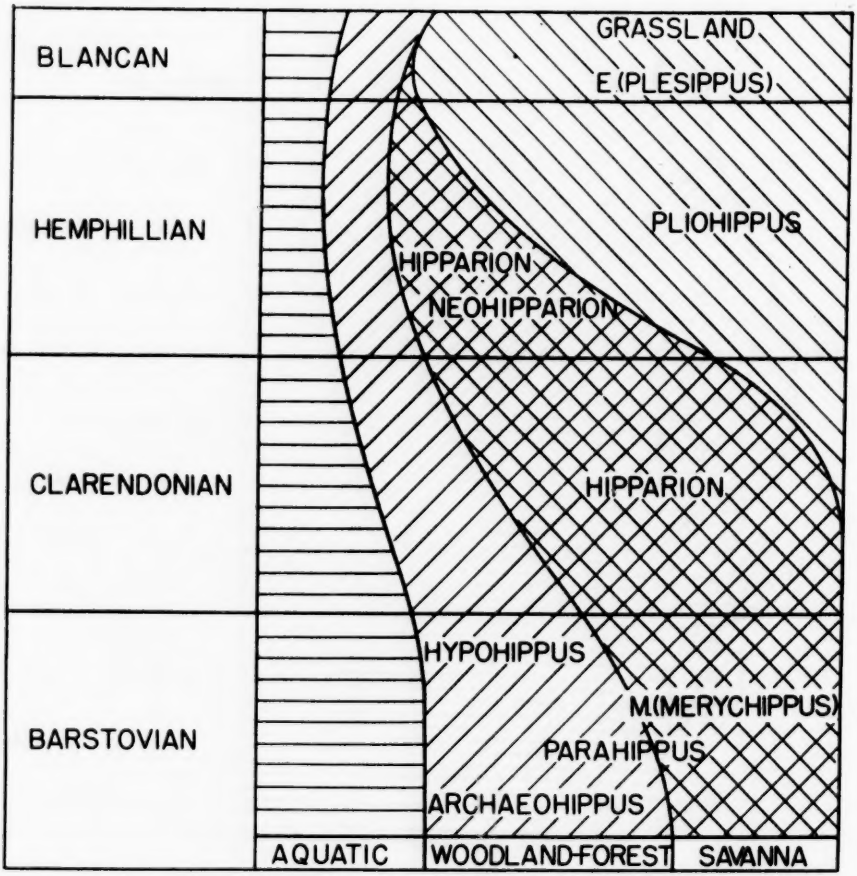


FIG. *10*—Changing proportion of aquatic, woodland-forest, savanna and grassland habitats of the Northern Great Basin in the Late Tertiary. Habitats occupied by various horses indicated.

However, the continued dessication of the Northern Great Basin is evident in the eventual loss of forest from the lowlands in this region and the occurrence of only dry, stream-border aspects of the Arcto-Tertiary Geoflora. This may be crudely generalized by saying that many of the environmental conditions in the Hemphillian of the Northern Great Basin are similar to those of the Southern Great Basin of the Clarendonian and the area south of the Great Basin in the Barstovian. This is not of course strictly true as concerns winter temperatures and affinities of the vegetation. The flora of the Northern Great Basin of the Hemphillian is not related very closely to that in the Barstovian of the south but is of similar form. The generalization serves to emphasize the northward movement of semi-arid conditions within the Great Basin.

Comparison of the vegetation maps (text-figs. 7–9) and the maps of grazing horse distribution show a correlation between the movement of drier conditions

into the Great Basin with the extension of the range of the single-toed horse *Pliohippus* into this area.

This drier vegetation included extensive grassland. The movement of *Pliohippus* into the Northern Great Basin thus seems to coincide with the appearance of extensive grasslands of prairie and plains type in the region. Although descriptions of individual fossil floras may cite the occurrence of grazing mammals as a basis for the inference of local grasslands there is abundant floristic evidence which also leads to this conclusion. The correlation of *Pliohippus* and grassland in time of appearance in the various portions of the Great Basin is demonstrated by independent lines of evidences. A more authoritative general account of vegetational change is present in Axelrod (1948, 1950). Discussions of specific floras may be found through the bibliographies of these two papers. I have drawn freely upon these works in the foregoing discussion.

Throughout the Late Tertiary, grasslands of small extent occurred in the Northern Great Basin in the form of woodland-savanna. These apparently supplied the grazing habitat of *M.* (*Merychippus*) of the Barstovian and the hipparion horses of the Clarendonian and Hemphillian. A number of facts demand this conclusion.

(1) Extensive grasslands are not present in the Northern Great Basin in the Barstovian and Clarendonian when the grazing *M.* (*Merychippus*) and hipparion horses are present. This is shown by the rich Miocene and early Pliocene forests.

(2) In areas where hipparion horses and *Pliohippus* are contemporaneous, the relative abundance of the hipparion horses is not significantly different than in areas where *Pliohippus* is absent (Shotwell 1958A) This suggests that they are not in direct competition, probably preferring different grazing habitats.

(3) In areas where these horses occur they sometimes are found in the same broad communities (Shotwell 1958A). This indicates that if they prefer different grassland habitats these habitats must be adjacent.

(4) In the Northern Great Basin these habitats must have been established at different times. The floristic evidence indicates that both these requirements are the case.

The correlation of so many events of grazing horse distribution with the known history of the distribution of vegetation demands the conclusion that vegetational change must have played a major role in the biogeographic history of these horses. There is no indication that these horses have replaced a potential competitor, for no major grazers are lost in the Northern Great Basin at the end of the Clarendonian. Major groups are lost at the end of the Hemphillian though, but these include the very horses we have discussed so are of no aid in the pursuit of other possible factors. Thus *Pliohippus* did not fill a vacated "niche" in the Northern Great Basin, but entered the area as a new zone appeared. This was an environment which in some aspects was well established in most other parts of western North America in the Clarendonian and to a lesser extent in the Barstovian.

## EVOLUTION OF EQUID HABITATS IN THE GREAT BASIN

The discussion to this point has been concerned entirely with grazing horses. Browsing horses are also known from the Great Basin in the Late Tertiary. They include: the large *Hypohippus* and diminutive *Archaeohippus* of the Barstovian, *Parahippus* is sometimes found in Barstovian faunas although it usually is more common in older faunas. *Parahippus* exhibits incipient grazer characteristics. Early species of this long-lived form are ancestral to *Merychippus*. More detailed descriptions of the characteristics and adaptations of these horses may be found in Stirton (1940) and Simpson (1951). In the Great Basin none of these browsing forms are known from faunas as late as Hemphillian.

The diversity of horses noted in this study, browsing, savanna and open grassland grazers, are found in ten or more genera in the Late Tertiary. They have quite different ranges in time in the Northern Great Basin. Browsers are known from the Barstovian and Clarendonian, savanna grazers from the Barstovian, Clarendonian and Hemphillian and open grassland grazers from the Hemphillian on. These characteristics of diversity and time range reflect the vegetational history of the region as previously discussed. This history may be de-

scribed as a trend towards drier conditions with reduction and retreat of forest and woodland from lowland areas. Axelrod (1950, text-fig. 4, P. 287), presents schematically this trend as it affects various vegetational types. If we regroup some of the plant assemblages so that such mixed vegetational types as savanna are represented we can make an estimate of the proportional area of specific habitats at various times in the Late Tertiary of the Northern Great Basin. It should be noted that this estimate is probably based largely on lowland conditions including to a lesser extent some adjacent highland characteristics. The changing proportion of aquatic habitats can be estimated from precipitation figures derived from the vegetational studies. Rainfall of 30–35 inches per year in the Barstovian was reduced to as little as 17 inches by the Hemphillian. This was undoubtedly reflected in a significant reduction of aquatic habitat available.

Text-fig. 8 is a schematic diagram illustrating the changing proportion of the various available habitats for mammals in the Late Tertiary of the Northern Great Basin. Superimposed on the diagram are the times of occurrence and apparent habitat preference of each of the various horses discussed.

If this chart were to be made for the southern Great Basin or still farther south in the Mohave it would differ in several respects. As the area of reference is shifted south grassland would appear earlier and some of the horses not known from the Great Basin would appear. Relative proportions of aquatic and woodland-forest habitats would decrease. This diagram illustrates the diversity of habitats and horses at any one time. The habitats may be considered adaptive zones which allow the contemporaneous existence of succeeding morphologic types.

## ADAPTIVE SIGNIFICANCE OF THE HIPPARION FOOT

It is noted above that *Pliohippus* and *Hipparion* are both occupants of the same region in the Hemphillian. But they apparently occupied different grassland habitats, open grassland and savanna respectively. These two grazing horses differ in many characteristics of the skull, dentition, and appendicular skeleton. The most commonly referred to of these characteristics, and of significance here, is the differences in feet. *Pliohippus* was single toed comparable to the modern horse, whereas *Hipparion* had three well developed toes, the middle the largest. Both of these horses possessed the ligamental springing mechanism in the foot found only in grazing horses (Camp and Smith, 1942). Many authors have considered the lateral toes in the three-toed spring foot to have had no special function. Simpson (1951) has recently suggested a buffer action for the lateral digits to protect the large toe from bending too far and thus avoiding sprains in the lower foot. He indicates a possible subsidiary function through the increase in support afforded the three-toed horse on soft ground.

It seems to me the best way to understand the adaptive significance of the *Hipparion* foot is to first consider the function of the simple three-toed foot of the earlier browsing horses, such as *Miohippus*, in their environment. Then we can compare the different requirements of the environment of *Hipparion* and note modifications in the foot. Previous studies have been hampered to some extent by the assumption that hipparion horses with the three-toed spring foot and the single-toed *Pliohippus* occupied the same habitat. This immediately made it difficult to understand the adaptive function of two such different feet to be used in the same set of environmental conditions. The present study has shown that these two kinds of feet are on horses occupying two different habitats; this may lead to a more satisfactory explanation of the nature of their functions.

The dentition of *Miohippus* of the late Oligocene and early Miocene indicates that it was a browser. Vegetation history places it in areas of woodland and forest. A browser which cannot conceal itself or stand off predators must be equipped to move swiftly through obstructed areas such as those of a woodland or forest. This requires both agility and speed. You need only watch and listen to a deer in such an environment to realize how successful an animal can be at this. The agility of woodland browsers is a combination of the ability to change direc-

tion quickly and to maintain traction. Speed is attained by lengthening and stiffening the metopodial portion of the foot and reducing the area in contact with the ground. Agility demands some flexibility and enough foot surface on the ground to give traction. These are in some respects two opposite demands on the morphology of the foot. These are and have been met by compromise and new techniques of running. Dodging can be accomplished by leaping or lunging sideways rather than turning the foot. This reduces the necessity for a flexible ankle and metapodials so that stiffening and lengthening of metapodials for speed is possible. Traction as contrasted to small surface of foot on the ground may be satisfied by several small hoofs or cleft hoofs. Some flexibility of metapodials and phalanges is necessary in order that the hoofs may spread on contact with the ground to insure the best traction with the least amount of actual contact surface. Artiodactyls have solved this in a more universal type foot than have Perissodactyls. They have enlarged and stiffened two metapodials by fusing them rather than the one of perissodactyls. This allows a lengthened and stiffened metapodial shaft but still supplies some flexibility for traction in the foot by having two toes in contact with the ground instead of one as in *Equus*. As a result artiodactyl feet are not so fundamentally varied in different habitats as are those of perissodactyls. Artiodactyls make the most of this universal style foot by slight changes and different styles of running in different habitats. For example, the deer leaps and bounds in order to avoid obstacles in the woods. The antelope living in open areas keeps its body in a single plane while running, not wasting movement by jumping. The floating run of the antelope demonstrates the efficiency of a combination of habit and morphology.

*Miohippus* had met the locomotor requirements of its woodland habitat with rather long metapodials for speed but still sufficiently flexible to allow spread of the toes for traction in dodging. The ankle joint of *Miohippus* is not more flexible laterally than that of the later horses as evidenced by the deep narrow valley between the ginglimi of the astragulus. Three small hoofs provide traction but also small area on the ground. The largest hoof was probably partially cleft, at least the bony part of it was, indicating a possible cleft in the hoof itself. It has been emphasized above that *Hipparion* was to be found in savannas, and not open grasslands. This differs from the woodland in that trees and shrubs which are both obstructions and concealment for predators are still present but widely dispersed as compared to the woodland. Moderate grasslands are present providing open areas. The requirements of a larger herbivorous mammal, in this case a grazer, are somewhat similar to those of the woodland browser except in the relative importance of various abilities. Agility in the form of the ability to dodge is still vital to survival; however, in the savanna it is not necessary to always dodge in order to move quickly through the habitat. Clear paths are ordinarily available. Dodging is still necessary to avoid unexpected obstacles or suddenly appearing predators. Where agility was the primary requisite of the browser in the woodland and speed of lesser importance, in the savanna the story is reversed and speed is primary, with agility necessary but less vital. In comparison with the foot of *Miohippus*, the foot of the savanna grazing horse is similar but with emphasis on the requirements of the environment in which it lived. Flexibility of the foot has been somewhat reduced, the metapodials are partially fused by ligaments leaving only the phalanges flexible. The three hoofs are still present but only one touches the ground except when the full weight of the animal is on that foot still allowing the traction necessary for dodging. The middle hoof is still cleft. The middle metapodial is stouter but proportionately little longer. The only new character in the foot is the ligamental springing mechanism which provides the increased speed in the more open habitat. Although the lateral toes of *Hipparion* and *Merychippus* possibly acted as buffers to protect the spring ligaments it seems more likely they retained a more basic purpose of added traction in dodging movements as they did in *Miohippus* which had no spring foot. It is concluded here that the lateral toes of the *Hipparion* horses were functional and that they reflect the running habits necessary for such an animal in areas

where obstructions are present. They supplied added traction in dodging maneuvers in an animal which could not turn its foot.

*Pliohippus* on the other hand occupied open grassland where high speed was necessary to escape from running rather than leaping predators. Agility then was a burden and speed the basic requirement. The foot of *Pliohippus*, as in *Equus*, exhibits only the adaptations of speed, and for speed in relatively straight lines. Jumping is only possible in the general direction of movement.

## CONCLUSIONS AND IMPLICATIONS

The discussion above leads to the following conclusions:

1. *Pliohippus* is a migrant into the Northern Great Basin in the Hemphillian. Its protohippine ancestors did not occur in this region.
2. The appearance of *Pliohippus* in the region coincides with the expansion of open grassland.
3. Previous grazing mammals (*Hipparion* and *M. Merychippus* in particular) occupied savanna grazing habitats.
4. Hipparion horses and *Pliohippus* are contemporaneous in the Great Basin in the Hemphillian.
5. The three-toed spring foot of *Hipparion* is functional. It provides the additional traction necessary to make sudden changes of direction by lunging.

The open grassland of the Hemphillian represents a new environment in the Northern Great Basin. The origin of members of the new communities which occupied it provides an ideal situation for studying community dynamics. The recognition of *Pliohippus* as a member immigrating from other regions is of importance in tracing the history of members of open grassland communities. As quantitative studies of these communities continue, it will be necessary to know the origin of each member species of the community; that is, has it evolved from resident groups in other communities or is it a migrant?

Savanna is emphasized here as an important equid environment of the Late Tertiary of the Great Basin. The great reduction of this habitat is suggested as an explanation for the extinction of hipparion horses by the end of the Hemphillian. Many other mammals also become extinct in the Great Basin by the end of the Hemphillian. These include rhinoceroses, aplodontid rodents, mylagaulid rodents, browsing horses and oreodonts. The loss of these forms may also be due to the loss of woodland and savanna as major habitats. It is of interest to note that where aplodontid rodents and rhinoceroses still survive these conditions of environment are also still in existence. Where these conditions persisted significantly longer such forms as Hipparion carried on much later.

A recent study (Shotwell 1958B) of the changes of distribution of aplodontid rodents showed them to be restricted to a particular floral element in the later Cenozoic. The present study demonstrates coincident changes in distribution of certain horses and extensive grassland. The grassland area occupied is derived from more than one floral element in various parts of the range of these horses. Here the restriction is to a vegetational type rather than a particular association of plants. The earlier study described the conditions of movement of a mammal out of the Great Basin, whereas the present study describes the movement of a mammal into the Great Basin. These opposite effects are apparently both reflections of the same vegetational changes.

The Hemphillian has been shown to be a period of important faunal interchange between North America and Eurasia (Simpson 1947; Shotwell 1956). Several forms involved in this interchange are known only from the Pacific Coast, suggesting that this area enjoyed good contact with the area of actual interchange. In this exchange of faunal elements a number of mammals that seemingly had the opportunity to migrate did not. *Pliohippus* is one of these. *Hipparion* on the other hand is a prominent migrant. It has been perplexing why one horse should migrate and another not. The results of the present study suggest that in the Hemphillian *Pliohippus* was no farther north on the Pacific Coast than the Blue Mountains of Oregon. Available evidence from the Great Plains is not indicative of the northward extension of *Pliohippus* at this time. The implication is that *Pliohippus* was not in the area proximal to the inter-

change, and thus did not have the opportunity to migrate to Eurasia. The probable absence of open grassland far enough north to allow *Pliohippus* to enter the area of interchange may account for this lack of migration into Asia. *Hipparion* on the other hand, as an occupant of the savanna found suitable conditions encircling the North Pacific area.

It should not be implied that homotaxial effects within *Pliohippus* are evident here, that is, the Clarendonian species of *Pliohippus* arrived in the Great Basin in the Hemphillian. There is no lag of species in time involved. Hemphillian species of *Pliohippus* of the Great Basin are similar in their evolutionary stage of development to Hemphillian species in other areas of North America. In fact one species, *Pliohippus spectans*, occurs in faunas both within and without the Great Basin of the Pacific Coast. It is sometimes suggested that difficulties between various chronologies in intercontinental correlation are due to migration time necessary. The present study demonstrates a delayed migration of *Pliohippus* into the Great Basin but without homotaxial effects; however, it is the Hipparion horses that are involved in controversies of intercontinental correlation. The present study demonstrates why they are not so susceptible to delays in migration. The environmental situations they apparently preferred were to be found over much of Eurasia, Africa and North America in "Mio-Pliocene" time.

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# REVIEW OF OLIGOCENE DIDELPHID MARSUPIALS

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## INTRODUCTORY REMARKS

SMALL marsupials very similar to the present day South American opossums are common in Oligocene deposits. Locally they may be very numerous. When the extremely small size—which can cause them to be overlooked by any collector not searching on hands and knees for small fossils—is considered, their relative abundance in Oligocene collections is surprising. Most of the specimens, however, are lower jaws, usually fragmentary. There are some upper dentitions and a few skulls. One skeleton has been described from the Florissant beds (Gazin, 1935). The small size and fragmentary nature of the specimens make classification extremely difficult. The current view, as reflected by the taxonomy is that the North American didelphids were an extremely conservative group, hardly differing generically from the Eocene to the Miocene and with virtually no speciation in the Oligocene.

McGrew (1939) in his description of *Nanodelphys* suggested that this idea, based on the conservatism of the dentition might by illusory. There is a rather wide diversity of habit among the living South American genera which is reflected in the foot structure rather than the dentition. A study of lower Oligocene specimens referred to *Peratherium* indicates rather clearly that McGrew's view is correct and that there were at least three genera of didelphids in the Oligocene and probably six or more species. It is still impossible to be more do than guess at the diversity of habit because the foot structure is still unknown in most genera. Differences in the skull and upper dentition and the mandible, however, parallel those of certain of the South American genera and would seem to indicate that there was a radiation of North American opossums in the Oligocene similar in kind and extent to that which has occurred in Recent times in South America.

The philosphosical basis of classification generally accepted among paleontologists today—in the United States at least—is that of moderate realism. Genera and species are regarded as real entities existing in nature. The job of the scientist is to deduce as correctly as possible the nature and limits of these entities from any information he can obtain from all of the individuals available for study. There is naturally a strong subjective element in this, but aside from that—even if complete objectivity were possible—there is still a wide margin or error because of the incompletness of knowledge. Even with modern animals only a small sample of a population is available, and this is very imperfectly known. Species of most mammals are based on characters of the skull and skin, with a few from the skeleton, and a very few from the soft parts, physiology and habits.

With fossils the problem is much more complex. Not only are only hard parts available for study, but only part of these parts, and in most instances, only fragments of these. Inference therefore plays a large role making paleontology at least as much of an art as a science. Imagination is important, not only in the ability to picture the mineralized bony parts as living animals which really existed in populations, but in a creative sense, the proper assessment of the importance of some characters or suites of character over others, for purposes of classification and bring order out of that would be a chaos of uniquely different individuals.

With some groups of mammals this is less difficult either because of the relative abundance and completeness of the specimens or because there are so few that a logical arrangement (although not probably a "natural" one) is comparatively simple. The Oligocene marsupials are among the most difficult fossils taxonomically because they fall between these two extremes. Specimens, in certain localities, are very abundant, so much so that they cannot be ignored. On the other hand, they are all fragmentary. No complete skeletons are known and very few fragmentary ones. No series of skulls have been discovered, the few which are known

are incomplete and so small and fragile that preparation which could exhibit all of the characters is extremely difficult. The majority of specimens are partial lower jaws many of which do not have the coronoid process or other of the more diagnostic parts present. The arrangement suggested here is, therefore, very tentative and is submitted as a basis for further work when better specimens are available.

### VARIATION IN *DIDELPHIS* MODERN DIDELPHIDS

The Didelphidae are both a very variable and a very conservative group. The essential characters of the skull and dentition have changed but little from Cretaceous times to the present. On the other hand, intra specific variation is so marked that classification, even of the modern forms, is is difficult. According to Allen (1901) and Tate (1933) this variation in the skull and jaws of *Didelphis* and *Marmosa* is due in part to sex and age but also in great measure to individual variation. Didelphids reach sexual maturity early but growth in the skull and jaws continue throughout life. This growth is not uniform. There is consequently not only a wide size range due to age but also a considerable variation in the proportions of the various parts. Even the configuration of these parts may change from youth to maturity. Certain features of this growth are particularly important in the study of Oligocene didelphids.

*1. Size as related to age, sex, etc.*

Didelphids reach sexual maturity early but growth in the skull and lower jaws continues throughout life. This makes for a wide range of linear measurement even for fully adult skulls from the same locality. In addition, there is considerable individual variation in size. Females, in general, have smaller skulls and smaller more delicate teeth and mandibles but very old females may approximate old males in size. The size of the individual teeth tends to remain the same. A number of combinations of proportions are therefore possible: (a) a slender mandible with large teeth indicating a young male, (b), a long deep mandible with large teeth indicating an old male, (c), a slender mandible with small teeth suggesting a young female, and (d), a longer deeper mandible with small teeth, possible an old female. In addition, although the tooth row tends to shorten by absorption in extreme old age, in the fully adult the individual teeth become less crowded. Spaces appear between the premolars and between the last molar and the base of the coronoid process.

*2. Configuration of the coronoid process*

The slope of the anterior margin of the coronoid process as well as the position of the last molar in relation to it changes with age. The last molar when it first appears is crowded against the anterior base of the coronoid process. With age a space develops between the last molar and the base of the process which may measure 6 to 10 mm. in length. The angle made by the coronoic process with the horizontal ramus of the mandible is at first nearly vertical but becomes gradually more open as the backward slope of the process increases. These two factors together make the mandible of an old individual appear quite different from that of an immature one or even a young adult.

*3. Absolute size of the teeth*

The size of the teeth is much less subject to variation than the size of the skull and mandible. There is a sexual difference and probably considerable individual variation but not much change with growth. The length of the molar dentition is used by Tate in his diagnosis of species of *Marmosa* although there is difficulty using this criterion because of the gradational nature of size differences and the overlapping of one species with another

*4. Character of M 4/4*

In *Marmosa* the last lower molar does not vary appreciably. The last upper molar, however, is considerably modified from group to group and species to species. In the *M. cinera* group the tooth is moderately long, its posterior portion bearing the metacone moderately prominent and the external stylar portion reduced. In the *M. elegans* group *M. venusta* has $M^4$ almost as long as in the *M. cinera* group with the stylar portion still more reduced and the metacone

as well as the paracone strongly developed. In *M. formosa* of the same group, the extreme of shortening is reached and the ridge which ordinarily joins the metacone to the outer edge of the tooth is undeveloped. In the murine section (and *M. microtarsus*) the tooth is also very narrow and the stylar portion heavily developed with the metacone compressed into the body of the tooth.

*5. The degree of inflection and position of the angle.*

These features are constant within species and even groups of species (sections) of *Marmosa* but differ somewhat from section to section. (See Tate, 1933, fig. 6.) The differences between genera are more pronounced.

*6. Relative size of canines and premolars*

In *Marmosa* the canines are generally uniform but in certain groups may be shortened and compressed. $P^1$ is almost universally small, but in *M. parvidens* it is almost as large as $P^2$; $P^2$ is generally larger than $P^3$. Only in the *M. elegans* group are $P^2$ and $P^3$ nearly equal.

VARIATION IN OLIGOCENE DIDELPHIDS

In his earliest description of the White River marsupials, Cope, (1873) referred all of the specimens known to him at that time to two genera *Herpetotherium* and *Embassis*. Later Cope, (1885) revised this opinion and included all of the species in the genus *Peratherium* established by Aymard (1850) for similar specimens from the Miocene of Ronzon, France, and other European localities. With the exception of a partial skull and mandible of *Peratherium fugax* the specimens described and figured by Cope consist of fragmentary lower jaws. On the basis of characters derived from these Cope distinguished six species, *Peratherium fugax*, *P. tricuspis*, *P. hunti*. *P. scalare*, *P. alternans* and *P. marginale*.

The differences by which Cope separated these species, namely, the relative size of the dentition and mandible, slope of the coronoid process, relative elevation of the molar cusps, and degree of separation of these cusps are quite real and easily distinguishable in the series of specimens which Cope described. The difficulty lies in determining whether they do or do not represent species distinctions.

Scott, (1941) reviewing the genus *Peratherium* in the White River monograph suggested that six species co-existing was an impossible number and, believing that most of the characters used by Cope as specific distinctions could be ascribed to individual or sexual variation, recognized only two species, *P. fugax*, composed of the larger specimens with spaces between the premolars, and *P. hunti*, composed of the smaller specimens with crowded premolars. This arrangement has an appealing simplicity but fitting the large number of specimens of *Peratherium* now known from a number of lower and middle Oligocene localities into these two categories is an impossibility. Moreover, the smaller specimens which are referred to *P. fugax* grade into the larger ones referred to *P. hunti*. The spacing of the premolars is also gradational and is an age character in modern didelphids. The result, therefore, of reducing Cope's original six species to two has been (1) a confusion as to what is *P. fugax*, and what *P. hunti* and (2) more important, lack of recognition of the great abundance and variety of didelphids in the Oligocene of North America.

It is quite true that six species probably did not co-exist in the same locality at the same time, but aside from the problem of exact contemporaneity always present in fossil faunas the probable explanation is that there are several genera. This is impossible to ascertain certainly from Cope's original specimens because they are too incomplete but from studies of a large number of specimens from Oligocene localities at least three genera seem recognizable. The distinction between these lies in the character of the angle of the mandible, certain characters of the upper dentition, especially $M^4$ which are linked with characters of the lower dentition noted by Cope.

Lavocat, (1951) has recently pointed out that the American species cannot be included in the genus *Peratherium* Aymard because all of the European specimens have the angle of the mandible characteristically inflected as in *Didelphis* whereas Cope described the type species of *Peratherium fugax* as lacking this inflection of the angle. There is actually wide variation of this character

in the American species. Cope's genus *Herpetotherium* is therefore revived to include those species in which the angle is uninflected. The remaining species are in part included in *Peratherium* Aymard because of the familiarity of the term and the fact that there is nothing in Lavocat's revised definition which would exclude a number of the American species and in part are placed in a new genus because of significant differences in the characters of the mandible and dentition.

### HERPETOTHERIUM Cope

*Generic type.*—*Herpetotherium fugax* Cope 1873

*Author's diagnosis.*—"Dental formula: I ?/4; c, 1/1; Pm., 3/3, M., 4/4. The superior canines are well developed. The premolars are compressed, with one apex, no inner lobes, and two roots. The superior molars, excepting the last, present two median V's, which would be termed external but for the fact that the external basal cingulum is elevated into a crest. A single internal lobe which is less elevated than the median. The last molar has but one median and one internal crest. . . . The inferior incisors are subequal and closely placed; the first three are parallel, unicuspid. Molars consisting of two V's with apices external. The inner extremity of each branch of the anterior V is a pointed cusp, behind which stands, on the inner edge of the crown, a third cusp opposite to the middle of the posterior V. The last inferior molar is a little shorter than the others, but the last V is narrowed so as to be only a heel.

"*Peratherium* is nearly allied to *Didelphis* but has not the inflected angle of the mandible of that genus. The difference in dentition . . . consists in the elevation of the median cusps of the superior true molars into V's and the obsolescence of the tubercles of the external series."

*Revised diagnosis.*—Angle of mandible uninflected or only very slightly so. Condyle high. Coronoid broad and high with strong backward inclination. Masseteric fossa shallow and broad, bounded anteriorly along the anterior rim of the coronoid process. Mandible in old adults very long and slender, tapering to a point. Lower margin convex with deepest point below $M_1$.

### HERPETOTHERIUM FUGAX Cope

*Herpetotherium fugax* Cope: Paleon. Bull., no. 15, p. 1, 1873.

*Peratherium fugax* Cope: Rep. of the U. S. Geol. Survey Territories, III, p. 794, 1884.

*Herpetotherium huntii* Cope: Synopsis New Vertebrata Colorado, p. 5, 1873. (but not *Herpetotherium stavensoni*, ibid. p. 6).

*Peratherium huntii* Rep. of the U. S. Geol. Survey Territories, v. III, p. 796, 1884.

*Type.*—AMNH 5254, Brule, Cedar Creek, Colorado.

*Referred specimens.*—USNM no. 20740 partial skull, jaws, some skeletal parts, no. 20741, partial skull and jaws.

*Diagnosis (revised from Cope).*—Teeth moderately large in proportion to the mandible, observed range of last two lower molars $M_3-M_4$, 3.1–3.8 mm. Upper molars broad, with internal cingular cusps broad, U shaped. $M^4$ with single median V, the apex of which is not much elevated over the external shelf. Stylar cusp C present but not conspicuous, absent in worn teeth. Mandible relatively slender, premolars widely spaced in old individuals, crowded in immature specimens. Difference in relative elevation of talonid and trigonid moderate. Cusps of trigonid not deeply separated from each other. Median external cusp higher than the two internal cusps but with less marked differences than in other species.

*Discussion.*—Cope's type, and the larger specimens referred to this species are old individuals and the characters by which Scott differentiated *P. fugax* from *P. hunti* are age characters. The two species are therefore here merged. In practice, however, it has become customary to recognize as *P. hunti* only the smallest specimens, smaller than Cope's type and with different dental characters. These properly belong in other genera. Some, as Galbreath noted, are probably lower dentitions of *Nanodelphys*, others are a small species of a different genus of didelphids which can be included in *Peratherium* because nothing in Lavocat's revised diagnosis excludes them. Cope's *Peratherium scalare* and Mathew's *Peratherium titanohelix* apparently belong to this genus but the diagnosis and description here given will be based on some Pipestone Springs specimens now in the National Museum, Washington, D. C. which have the posterior part of the mandible complete enough to show the strong inflection of the angle, and which are associated with upper dentitions.

PARATHERIUM Aymard 1846

*Type.—Didelphis crassum* Aymard 1846. *Peratherium crassum* Aymard, in Gervais (1848, p. 134, 1859, p. 266)

*Generic description.*—(Revised on basis of American forms.) Small to minute sized didelphids with the angle of the mandible strongly inflected as in the marine opossums: ramus of the jaw slender, lower margin curved: teeth relatively large: $M_4$ larger and higher than $M_3$. Coronoid process sloping. Cusps of molars high with the protoconid higher than the metaconid: trigonid elevated above the talonid: entoconid very prominent: hypoconulid internally placed, strongly developed on $M_4$.

PERATHERIUM DONOHOEI n. sp.
Test-fig. 1

*Type:* USNM no. 20740, left ramus with $M_2$–$M_4$. Coronoid process and angle almost complete.

*Referred specimens:* USNM no. 20081 $P_4$–$M_3$. CM 1017, left ramus $M_3$–$M_4$, USNM 20086, right ramus $M_3$–$M_4$, CM 8902 right ramus $M_3$–$M_4$. USNM no. 20167, fragment right ramus $M_2$–$M_3$, 20742, maxilla $M^1$–$M^4$.

*Locality.*—Pipestone Springs, Montana

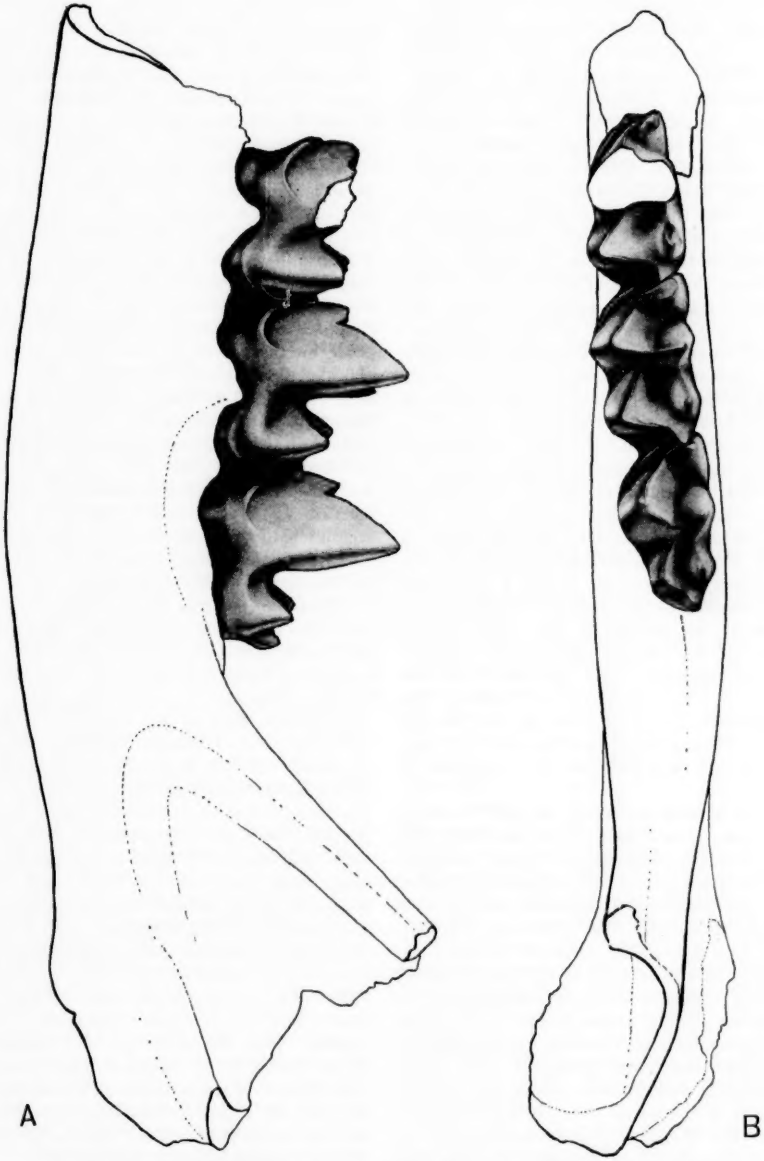
*Diagnosis.*—Small Oligocene didelphids about the size of *Marmota alstoni alstoni.* Teeth uncrowded. Jaw tapering, with greatest depth below $M_1$–$M_3$–$M_4$ measuring 3.8–4.0 observed range.

*Description.—Mandible and lower dentition.*—The mandible is slender and tapers to a point anteriorly. Posteriorly the lower margin curves gently upward at the base of the coronoid process. The coronoid process is high, slender and slopes posteriorly at an angle of about 130 degrees. The type is apparently a young adult with the teeth only slightly worn, $M_4$ separated by a space from the anterior margin of the coronoid process which has a moderate slope. The masseteric fossa is narrow but very deep. It is bounded by strong ridges which do not extend anteriorly beyond the anterior margin of the coronoid process which has a moderate slope. The masseteric foss is narrow but very deep. It is bounded by strong ridges which do not extend anteriorly beyond the anterior margin of the coronoid process. The lower ridge is well above the lower margin of the horizontal ramus. The angle is strongly inflected at an oblique angle so that the narrow internal shelf is partially visible from a lateral view.

The molars in the type and referred specimens have very high distinct cusps. The trigonid is considerably elevated over the talonid. The protoconid, which has a very prominent anterior and posterior basal cingulum is very high and sharp—very much more elevated than the metaconid and paraconid although these cusps are also well-developed. They are separated from each other by a deep cleft which persists to a late stage of wear. The paraconid is somewhat smaller and lower than the metaconid and is separated from the protoconid by a concave ridge. In worn teeth, the protoconid becomes extremely prominent. The paraconid and metaconid are eliminated as distinct cusps but form a high internal ridge notched slightly in the center. The top of the crown is basin-shaped. The posterior triangle in unworn teeth is sharply triangular in shape with a low, distinct hypoconid at the apex of the triangle. Midway along the internal margin the entoconid forms a very high columnar shaped cusp. The hypoconulid is poorly developed and situated internally forming the postero-internal corner of the triangle. In worn teeth, the hypoconid is reduced, the entoconid still a prominent cusp. The surface of the talonid is deeply basined with the entoconid and hypoconulid forming a strong internal rim. $M_4$ is large, with higher cusps than $M_3$. The protonconid is particularly high, the two internal cusps relatively lower by comparison. In worn teeth this character becomes even more pronounced, the protoconid being virtually the only cusp with the paraconid and metaconid almost obliterated. The talonid is relatively long anteroposteriorly but narrow transversely. It is deeply basined. Three cusps, almost equally spaced, form the posterior rim. The hypoconulid is a prominent cusp placed clmost medially along this rim.

*Upper dentition.*—Two maxillas with $M^1$–$M^4$ from Pipestone Springs and one from Cameron Springs are referred to this species because of their large size and association with the lower jaws. None were found occluded.

The upper molars differ from those of




TEXT-FIG. *1*—*Peratherium donohoei*. A, lateral view of left ramus with $M_2$–$M_4$; B, crown view of left ramus with $M_2$–$M_4$, both ×10, USNM 20740.

*Herpetotherium fugax* in being longer antero-posteriorly and shorter transversely. $M^1$ is shorter and broader than the succeeding teeth. The paraconal triangle is smaller and lower than the metaconal triangle. The two are separated by a deep U-shaped notch. The internal cingular shelf is very much lower than the paracone and metacone and has a U-shaped margin. A convexity along the posterior border markd the position of a small cuspule just internal of the base of the metacone. A cingular shelf surrounds the margin of the tooth from the antero-external shelf where it forms the small triangular "ear" of the postero-external corner. There is a marked convexity of the enamel ridge along the external margin of the tooth. Stylar cusp C is present as a low cuspule in unworn teeth.

$M^2$ is larger than $M^1$. The paracone is smaller than the metacone and lower, the disparity being greater than in $M^1$ Cuspule A is prominent, occupying almost all of the cingular shelf which forms the ear. B is not is not present as a distinct cuspule. C. is a large cusp situated just within a convexity of the enamel of the external margin almost opposite the center of the notch which separated the paracone and metacone. The external cingular shelf extends from the antero-external corner of the tooth to the postero-external. The internal shelf is like that of $M^1$ but the cuspule between the protocone and the base of the metacone is larger.

$M^3$ is almost the same size as $M^2$ but is narrower transversely. The paracone and metacone are more nearly equal in height but the metacone is still considerably higher than the paracone. Cuspules A and B form a more prominent "ear" than in $M^2$. Cuspule C is a rounded eminence situated internally of the margin of the tooth almost directly opposite the notch separating the paracone and metacone. D and E are prominent cuspules which form a distinct ridge at the postero-external margin of the tooth. A cingular shelf extends along the external margin of the tooth which is more concave than that of the preceding molars. The internal cingular shelf is essentially like that of $M^2$, except that cuspule between the protocone and the base of the metacone is smaller.

$M^4$ in this species is a large tooth with a prominent metacone, differing in these respects and in its configuration generally very markedly from that of *Herpetotherium fugax*. The relative size of the tooth is nearly that of *Peratherium merriami* but the metacone is more distinctly developed forming an abortive triangle almost as broad as the paraconal triangle. The postero-external part of the tooth is reduced but this reduction is as great as in *Herpetotherium fugax*. There is a cluster of small cuspules on the cingular shelf which forms the "ear" at the antero-external corner and a small high cuspule (Cusp C) in the center of the sloping posterior margin of the tooth. The internal cingular shelf is well developed almost as long and broad as that of $M^3$. It surrounds the entire inner margin of the tooth a such a way that the ridge running externally and posteriorly from the protocone connects with the base of the metacone. In *Herpetotherium fugax* the entire tooth is much smaller, and the cingular shelf very narrow. The protocone forms a crescent shaped cusp not connected with the metacone.

*Discussion.*—From the characters of the dentition it seem probable that Cope's type of *Peratherium scalare* and a large number of specimens from a lower Brule Round Top locality, Dawes Co., Nebraska, belong to this species. Two of the Round Top specimens in the Chicago Natural History Museum CNHM P 15329 and CNHM P 25652 have enough of the posterior part of the mandible to show that the angle was inflected. They are not complete enough to show the degree of inflection. The dental characters, however, of these and of a majority of the Round Top specimens, approximately 50 jaw fragments and 6 upper dentitions are almost indistinguishable from those of *Peratherium donohoei*. The only difference—a very slight one—is that the last molar is the same size, or slightly smaller than $M_3$ whereas in *P. donohoei*, $M_4$ is distinctly the larger of the two teeth. The Round Top specimens differing as they do from the Pipestone species geographically as well as stratigraphically probably represent at least a different sub-species.

In addition to the lower jaws with the characters just noted there are others in the collection which have the tooth size of *P.*

*donohoeii* but a deeper jaw. They are all old individuals. This difference may be due entirely to age, or they may belong to *Herpetotherium fugax*. None are complete enough for the determination of this point.

The upper dentitions from the Round Top locality present an interesting variation in $M^4$. On the basis of the configuration of this tooth they can be divided into two groups. In group 1, the individuals of which are somewhat larger, $M^4$ is a large tooth with a small metaconal triangle. The internal cingular cusp is crescent shaped and extends posteriorly to the posterior margin of the metaconal triangle. The outline of the tooth is that of an equilateral triangle. The stylar cusps are not prominant, the parastyle not being extended beyond the tip of $M^3$ and not hooked. Group 2 has a much reduced, very slender $M^4$ with an extremely oblique posterior margin. The paraconal triangle is sharply elevated. There is no posterior triangle. The metaconal (or stylar) cusp is only faintly developed along the posterior margin. The parastyle is hooklike extended over the metastyle of $M^3$. The internal cingular cusp is a sharp V, the sides of which extend only $\frac{1}{2}$ the distance from the protocone to the metacone. Stylar cusp C is very prominent.

PERATHERIUM TITANELIX (Matthew)

*Type.*—AMNH no. 9603, lower jaw with $P_3$, $M_2$–$M_4$, alveoli of remaining teeth except incisors. Coronoid process not complete enough to show angle.

*Locality and horizon.*—Lower Oligocene of Pipestone Springs, Montana *Referred specimens*: CM 9555, left ramus with $M_1$–$M_4$, alveoli of premolars; CM 9313, left ramus with $M_3$, $M_4$ both young individuals.

*Description.*—This species is characterized by extreme small size. The observed range of the last three molars, $M_2$–$M_4$ varies from 3.6 mm. in the Carnegie Museum specimens, both young individuals to 4.2 mm. in the type. The molars are crowded in such a way that there is a slight overlap. The trigonid, however, has three cusps, all very prominent in unworn teeth. The heel of $M_4$ is large and tricuspid. There is a distinct external cingulum at the base of the protoconid, similar to that of the larger species *P. donohoei*.

The ramus of the jaw is slender, the proportions and controur of the mandible similar to those of *P. donohoei*. As far as can be ascertained from the specimens which have portions of the angle intact this was inflected in a similar manner.

No upper dentitions were associated with these jaws and there are none in the collections which seem small enough to belong to this species. This is not surprising inasmuch as lower jaws are always more numerous than upper jaws, and large sized specimens much more numerous than the smaller ones.

DIDELPHIDECTES n. gen.

*Generic type.—Didelphidectes pumilis n. sp.*

*Diagnosis.*—The generic and specific diagnosis are the same until more than one species is described. See discussion below.

DIDELPHIDECTES PUMILIS n. gen. n. sp.
Text-fig. 2

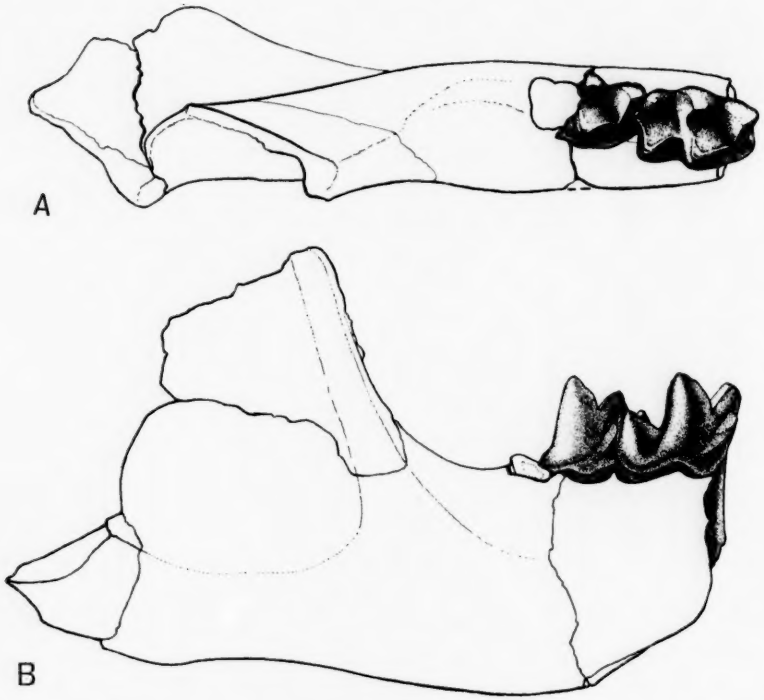
*Type.*—USNM no. 20084, right ramus, $M_3$–$M_4$, angle and coronoid process almost complete.

*Locality and horizon.*—Lower Oligocene of Pipestone Spring, Montana.

*Referred specimens.* CM no. 6644, maxilla with $M_1$–$M_4$, Lower Oligocene, Pipestone Springs, Montana; USNM no. 20747, left famus of mandible with $M_3$ and $M_4$ part of angle and coronoid process intact; USNM no. 20749, maxilla with $P_2$–$M_3$, both mandible and maxilla from Cook Ranch type locality of Wood, Sage Creek area, Beaverhead Co., Montana.

*Diagnosis and description.—Mandible and lower dentition.*—The angle of the mandible is strongly inflected with the inner shelf broader and more extended anteriorly than in *Peratherium*. The anterior margin of the coronoid process is almost vertical even in the type mandible which is that of a fully adult individual. The masseteric fossa is strongly developed, bounded by a strong ridge which extends anteriorly to a point below the last molar. The inferior dental foramen is very large.

The teeth are small in proportion to the depth of the mandible $M_3$–$M_4$ measuring 2.7 mm., in antero-posterior length, the depth of the jaw below $M_4$ is 2.5 mm. (Compare 1.9 depth of jaw of *P. titanelix*). $M_4$ is




TEXT-FIG. 2—*Didelphidectes pumilis*. A, crown view of right ramus $M_3$-$M_4$; B, lateral view of right ramus with $M_3$–$M_4$, both ×15. USNM 20084.

the smallest of the molars. Metaconid and paraconid of all the molars are strongly developed, almost of equal size, separated from each other and from the protoconid by a deep notch. The protoconid is only slightly higher than the internal cusps. There is great disparity in the height of the trigonid and talonid, the latter very much lower in comparison to those cusps in *Peratherium*. The talonid of $M_4$ is very narrow and has no hypoconulid.

*Upper dentition*.—The following description is based on referred specimens which were not included in the type because their association with the type lower jaw, although probable, cannot at present be proved. The maxilla and mandibular fragment from the Cook Ranch type locality were found together. The Pipestone maxilla, CM no. 6644, and others similar to it, are the same size and are not separable by dental characters from the Cook Ranch specimen.

The size is about that of *Nanodelphys*, perhaps slightly larger than the type of *Nanodelphys minutus*, but the teeth are differently proportioned. $M^1$ is broadly triangular in outline. The anterior and posterior triangles are subequal in size with the posterior triangle higher and broader. They are separated by a broad U. The antero-external cingulum is strongly produced into a narrow triangular shelf. Stylar cusp A is indicated by a rounded eminence on the antero-external border of the tooth just above this shelf. Stylar cusp B is evidently not present. C is extremely large and posteriorly placed forming the posterior wall of the deep notch in the external margin just opposite the V which separates the anterior

and posterior triangles. Cusps D and E are not present, but the posterior shelf is produced in an elongate "ear." The protoconal shelf is triangular in shape, deeply basined, considerably lower than the crown of the tooth. A small conule is present about two thirds of the distance between the protocone and the base of the metacone.

$M^2$ is somewhat larger than $M^1$. The para and metacones are nearly equal in width, but the metacone is much higher than the paracone. Stylar cusp A is distinct forming a small knob at the antero-external corner of the narrow cingular shelf surrounds the anterior margin of the tooth and joins the protoconal shelf medially. Stylar cusp B is a small rounded cuspule connected with the paracone by a ridge which forms the entire margin of the paraconal triangle. Cusp C is very large and high with a minute accessory cuspule. It is situated almost in the center of the external margin of the tooth just opposite the anterior margin of the posterior triangle. Cusps D and E are not present. The postero-external margin of the tooth is produced into an elongate "ear" much as in $M^2$. The protoconal shelf is triangular in shape, deep, with a sharply developed crescentic protocone. A crescentic metaconule is present between the protocone and the base of the metacone. The external margin of the tooth is almost straight.

$M^3$ is somewhat narrower antero-posteriorly than $M^2$. The antero-external cingular shelf is narrow and very short being little more than a small triangular process slightly below the level of the antero-external corner of the tooth. It is connected with the protoconal shelf by a low ridge. Stylar cusps A and B are not prominent although B is indicated. Cusp C is large and rounded but without accessory cuspules. It is placed almost in the exact center of the external margin of the tooth. The margin is deeply cleft in a symmetrical fashion so that the posterior "ear" has almost the same size as the anterior one. Both are directed outwardly. The paracone and metacone are almost equal in width but the metacone is very much higher. The protoconal shelf is narrower and more pointed than in $M^2$ and the metaconule less well developed.

$M^4$ is not present in USNM no. 20749 but is present in referred specimens CM 6644 and CM 6542. The tooth is relatively large in both these specimens, almost as long as $M^3$. The postero-external portion is more reduced than in *Peratherium donohoei* but less reduced than in *Herpetotherium fugax*. The paracone is a high cusp connected by a ridge with the prominent stylar cusp B. Posteriorly the ridge continues to the external margin of the tooth just anterior of the metacone. This cusp is smaller than the paracone but is high and well developed. Stylar cusp C is situated midway along the oblique external margin. The protoconal shelf is almost as large as that of $M^3$ but shallower. It continues around the posterior margin of the tooth to connect with the base of the metacone.

### NANODELPHYS McGrew, 1937

*Generic type.—Nanodelphys minutus* McGrew.

*Author's diagnosis.*—$M^2$ and $M^3$ possess the following characters: median stylar cusps absent; stylar cusps B prominent; paracone and metacone subequal; external shelf bilobate; paracone and metacone in middle of transverse diameter of the tooth; size small.

### NANODELPHYS MINUTUS McGrew

*Type.*—FM no. P 25708, portion of left maxillary with $M^2$ and $M^3$ slightly worn.

*Referred specimens.*—USNM no. 20744, maxilla, $M^2$–$M^4$, Harrison Ranch, 20 miles n. w. of Crawford County, Nebraska; USNM no. 20745, left ramus $M_2$–$M_3$, 5 miles south of Scenic, Pennington County, South Dakota; CHNM P 15238, lower Brule beds, 6 miles north of Gault, Weld County, Colorado, P. M. 374, Round Top locality, Dawes County, Nebraska.

*Discussion.*—This species is distinguishable from the smaller species of *Didelphidectes pumilis* by the sharply triangular upper molars; the subequal height of the metacone; the absence of the stylar cusp C, the narrowness of the protoconal shelf, the pronounced reduction of $M^4$.

Certain lower dentitions of minute size differ markedly from other smaller dentitions of Oligocene opossums in ways which seem conformable to the upper dentition of *Nanodelphys minutus*. These are tentatively

referred to that species and a description given as a basis for further study.

*Diagnosis of lower dentition of Nanodelphys.*—Size minute. Teeth small in relation to depth of ramus,—very small as compared to the tooth size of other Oligocene opossums. Jaw very slender. Coronoid process almost vertical. Mandibular angle extended posteriorly but not inflected.

Teeth very distinctive. $P_3$ smaller proportionally to $M_1$ than in other genera of oppossums, tip of crown below tip of protoconid of $M_1$. Cusps of trigonic of $M_1$ so close together as to appear almost in an anterior posterior line. Protoconid higher than internal cusps. Antero-internal cusp very low. Talonid divided from tigonid by deep groove. Hypoconulid very little developed and placed internally. Entoconid prominent. Talonid appears basined rather than triangular and is broader than the trigonid of $M_1$ and $M_2$. The trigonid and talonid appear about the same width in $M_3$, the talonid much the smaller of the two in $M_4$.

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# PALEONTOLOGICAL NOTES

## THE CAMBRIAN GASTROPOD *CLOUDIA BUTTSI* IN MISSOURI[1]

RICHARD ZIMMERMANN AND ELLIS L. YOCHELSON

Dept. of Geology, Missouri School of Mines, Rolla, Missouri and
U. S. Geological Survey, Washington 25, D. C.

In the fall of 1958, during a visit to Zimmermann's thesis area in Southeast Missouri, G. C. Amstutz and Richard Zimmermann of the Missouri School of Mines found a fossil gastropod subsequently identified as *Cloudia buttsi* Knight. Because of its unusual geographic occurrence, and the paucity of fossils in the area, it is considered worthwhile to note this locality. Thus far, this gastropod is the only fossil found in an area of about 50 square miles.

The specimen is an incomplete sandstone steinkern approximately 23 mm. in length and 10 mm. in width. About two and one half whorls are preserved beyond the earliest growth stages (figure 3). The dorsal profile is little arched, as may be seen in figure 2, thus being more similar to a paratype (Knight, 1947, pl. 2, fig. 1b) than to the holotype. It is rounded only along the median crest. The umbilici are deep and widely phaneromphalous (figure 1). The umbilical walls are nearly vertical for most of their width, their outer portion curving abruptly, but smoothly, around the side and onto the dorsum. No trace of growth lines can be observed.

The fossil locality is near the middle of a 10 foot bluff along the sharp curve in Missouri State Highway 49 at the center of S. E. $\frac{1}{4}$, sect. 15, T. 31 N., R. 3 E. (Des Arc Quadrangle), about one-quarter mile north of Annapolis, Missouri. The rocks along the bluff consist of massive beds of medium grained dolomite with abundant rusty colored, thinly cellular quartz druse. There are faint indications of crossbedding in this particular outcrop. At other outcrops crossbedding is well shown in the same beds.

Recent field work and detailed mapping (Zimmermann, 1959), suggests that these beds probably belong to the undifferentiated Derby and Doe Run dolomites of Late Cambrian age, rather than to the Potosi dolomite as considered by Dake (1930). A stratigraphic problem exists in the area since field work has shown that the lithology of the beds under investigation grade laterally. The lateral gradation may have been caused by the irregularity of the Precambrian topography at the time of deposition as the sedimentary rocks were deposited between

[1] Publication authorized by the Director, U. S. Geological Survey, Washington 25, D. C.

TEXT-FIGS. *1–3*—*Cloudia buttsi* Knight. Hypotype, U. S. National Museum No. 138776; all views twice natural size. *1*, right side view. *2*, view of dorsum. *3*, slightly oblique left side view.

knobs or ranges of hills of Precambrian porphyries.

*Cloudia buttsi* has hitherto been known only from Alabama where it occurs in "the lower part of the middle third of the Copper Ridge dolomite . . ." (Knight, 1947, p. 6) in beds thought to be equivalent to either the Trempeleau stage or, less likely, the upper part of the Franconian stage of the Upper Cambrian. The occurrence in beds considered to be Derby-Doe Run, the Franconia equivalent in Missouri, would seem to confirm the lower range of this species. An alternative hypothesis is that this species is limited to Trempeleau equivalents in Alabama and that the occurrence reported in Missouri is from younger beds, as originally assigned by Dake. Neither hypothesis can be preferred until the stratigraphic occurrence of the species is known elsewhere. As this is the first reported occurrence of *C. buttsi* outside of the southern Appalachian region it is hoped that calling it to the attention of others will result in the publishing of more information regarding the range of this species.

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## A *PLACENTICERAS* WITH FEATHER STRUCTURE

OTTO HAAS

The American Museum of Natural History, New York, and Hofstra College, Hempstead, N. Y.

While I rearranged the fossil collections of Hofstra College, my attention was aroused by an ammonite labeled "Bad Lands, S. D." and readily identifiable as *Placenticeras whitfieldi* Hyatt whose outer whorl clearly shows feather structure (Arkell et al., 1957, p. L92, fig. 137) on the inner, nacreous shell layer.

This feature has been previously described, in the same species, as "divaricating ridges" by Meek and as "lateral chevrons with the apices pointing orad and occurring only on the outer thirds of the sides of the shell" by Hyatt (1903, p. 223) who also illustrated this character in both the typical form and in the var. *tuberculata* of his species (*ibid.*, pl. 47, figs. 3–5).

Still, it is so clearly exhibited by the specimen in the Hofstra collection that it seems worth while figuring (text-fig. 1).

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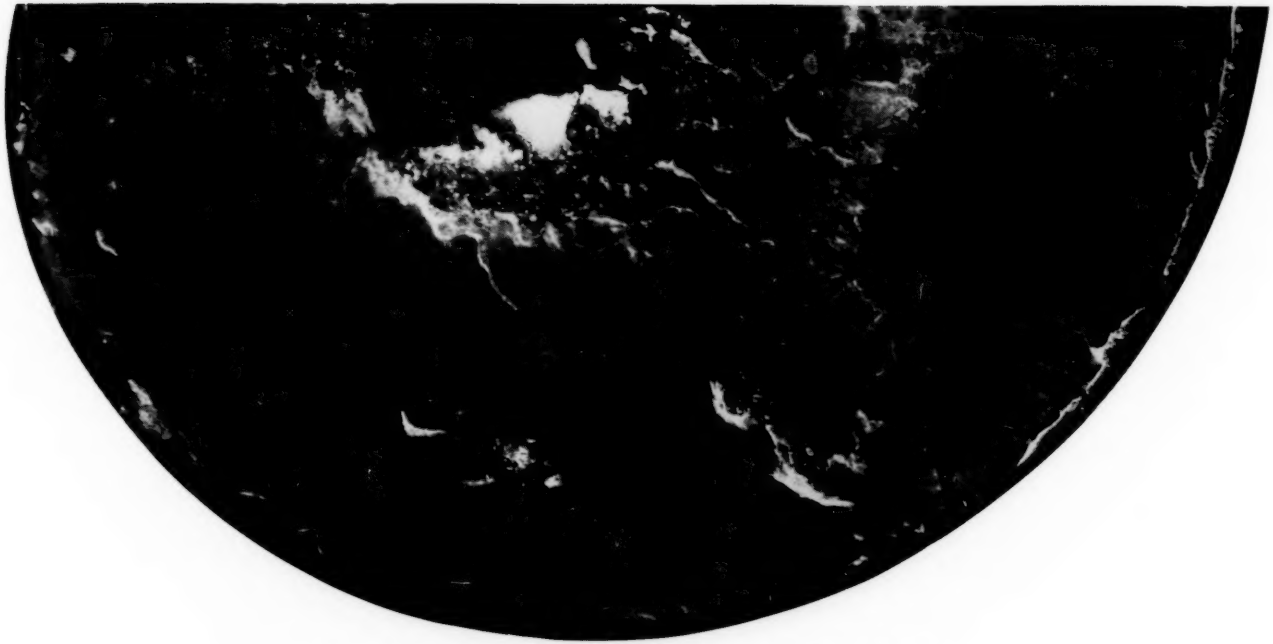
*(See text figure on facing page)*

## CORRECTION

Text-figure 2, "On the Occurrence of *Edmontosaurus* in the Hell Creek Formation of Montana," *Journal of Paleontology*, v. 34, no. 3, p. 465, May, 1960, should read, for the basal Hell Creek section, "Shale, dark brownish black"; and, for the Fox Hills section, "Sandstone, light gray, very fine grained, noncalcareous, and siltstone."

W. L. ROHRER



TEXT-FIG. 1—*Placenticeras whitfieldi* Hyatt; view of part of left side, ×1.

# NOTICES

## PROPOSED DUES INCREASE FOR THE PALEONTOLOGICAL SOCIETY

The *Journal of Paleontology*, published jointly by the Society of Economic Paleontologists and Mineralogists and the Paleontological Society, has long been one of the foremost paleontological periodicals in the world, establishing very high standards for the profession in illustrations and format. In 1957, the cost of publication of the *Journal* increased by 17%, and, in 1960, by another 9%. There is every indication that this trend will continue in the future. At this critical time, the Geological Society of America, which has most generously given financial aid to the Paleontological Society for publication of the *Journal*, is forced to withdraw this aid. The continuously increasing cost of publication of the *Journal* must be met immediately if the high standards and present scale of publication of the *Journal* are to be maintained. Consequently, the Council of the Paleontological Society is urgently proposing to the membership of the Society an increase in dues from $10 to $12, to become effective in January, 1962. Ballots for voting on this proposal will be sent to the members approximately two months after publication of this notice, as provided for in the by-laws of the Society.

NORMAN D. NEWELL
*President*
*Paleontological Society*

Beginning with the date of this notice, all manuscripts with more than 4 plates submitted for publication in the Paleontological Society's numbers of the *Journal of Paleontology* must have the cost of the additional plates borne by the author.

ERWIN C. STUMM
ROBERT V. KESLING, *editors.*

# SOCIETY RECORDS AND ACTIVITIES

## THE PALEONTOLOGICAL SOCIETY

### PROCEEDINGS OF THE FIFTY-SECOND ANNUAL MEETING

### HELD AT DENVER, COLORADO

### OCTOBER 31–NOVEMBER 2, 1960

H. B. WHITTINGTON, *Secretary*

#### BUSINESS MEETING

The Annual Business Meeting of the Society was called to order at 1:30 P.M., Monday, October 31st, with President Kenneth E. Caster in the chair, and about 100 members in attendance.

The Officers gave their respective reports, and a report of the work of the Treatise Committee was given by Professor Raymond C. Moore. These reports are given below. Verification by Council of the annual ballot for Officers was announced. Those elected to serve from the time of the fifty-second Annual Meeting until the next meeting in November 1961 are:

*President*—Norman D. Newell, New York N. Y.
*Vice President*—Siemon W. Muller, Stanford, Calif.
*Editor*—E. C. Stumm, Ann Arbor, Mich.
*Treasurer*—C. C. Albritton, Jr., Dallas, Texas
*Secretary*—H. B. Whittington, Cambridge, Mass.

The incoming President, Norman D. Newell, was introduced and announced the nominations for Society Officers for the year 1961–1962. These nominations are given in a separate notice below. In accordance with the changes in the By-Laws voted by the membership, a committee will be appointed by the President to prepare nominations for Society Officers for the year 1962–1963.

#### ANNUAL LUNCHEON

Held at the Petroleum Club on 2nd November, 110 members attending. Photographs of the proposed design for the Medal were exhibited, and comments on the design invited. President Caster gave his address entitled "Enigmatic Paleontology" (see pp. 238–240).

#### REPORT OF THE COUNCIL

The Council met for 7 hours on Sunday, 30th October. Apologies were received from F. M. Swartz, J. W. Wells, and O. L. Bandy. N. D. Newell and E. C. Stumm were present as members of the Council elect, A. R. Palmer as representative on A.G.I., F. D. Holland as Chairman of the committee on membership, R. L. Langenheim as councillor of Pacific Coast section, C. W. Collinson and W. M. Furnish as non-voting members representing S.E.P.M.

Dr. Frederick Betz, Jr., Secretary of the Geological Society of America, kindly appeared before the Council to explain in detail the reasons why the Council of the G.S.A. decided in April, 1960 to reduce the traditional subsidy to the P.S. ($6500 per year in recent years). This reduction is to take place over five years, diminishing to zero in 1964–1965. In addition the Society faces an immediate rise of 9.3 percent in printing costs of the *Journal*. As a first step to offset both the loss of subsidy and increased costs, Council proposes that dues be raised to $12.00, and the membership will be balloted on this question. A second step is the establishment of a permanent Publication Fund, contributions to which are noted in the Treasurer's report.

G. A. Cooper reported for the committee appointed to prepare a design for the Paleontological Society Medal. The committee is to remain active, and it is hoped that a final design and rules of award will be formulated by November 1961. The report of the Membership Committee was accepted and the committee is to remain active. Council voted that a grant of $50.00 be made this year to the Zoological Record fund of the Zoological Society of London, and that the Paleontological Society should adhere to the International Paleontological Union. It was

voted to continue the 300 line screen half tone reproduction for plates until contrary recommendations are introduced by the Editor. It was also voted that not more than four plates per paper will be accepted without subsidy of the cost of plates. A membership list of the Society is to be published every two years in the May issue of the *Journal*.

A hearty vote of thanks to the local committee for the arrangements made for the meetings is to be conveyed by the Secretary.

### REPORT TO THE SECRETARY

I have the honor to submit the following report for the year ending 31 October 1960:

Thanks to the activity of the Membership Committee under the Chairmanship of F. D. Holland, Jr. 120 new proposals for membership have been received during the year. The membership now totals 942, 105 more than at this time last year.

During the year the Society has lost 8 members by death:

J. Brooks Knight
James D. Bump
Mrs. J. H. Renfro
Bela Hubbard
Clinton R. Stauffer
Paul Bartsch
Hubert G. Schenck

Respectfully submitted,
H. B. WHITTINGTON
*Secretary*

31st October, 1960

### AUDITOR'S REPORT

We have examined the Treasurer's Report, here appended, and the vouchers, check book, and bank statements in the Treasurer's Office, and find them to be in order and correct as reported.

Yours very truly,
J. S. BRADLEY
R. J. CORDELL

### REPORT OF THE TREASURER

I have the honor to submit the following report on the finances of the Society, covering the year from August 1, 1959 to July31, 1960, inclusive.

Because the voucher authorizing payment for printing the May issue of the *Journal of Paleontology* was not received prior to the closing of the books, the cash-on-hand is greater by $4,075.76 than it should be. Otherwise the Society carries no unpaid obligations into the new year.

Toward the establishment of a permanent publication fund, The Paleontological Society of Washington contributed an initial deposit for a savings account opened last February at the Hillcrest State Bank of University Park. This account has also received special contributions from individual members honoring the memory of J. Brookes Knight.

Despite a substantial cash reserve, the Society is now confronted with a financial emergency. The Geological Society of America is withdrawing its support of our publication program by successive annual decrements of twenty percent. In addition, our printer has served notice that his prices will soon be increased by about ten percent.

In fairness to our principal benefactor, it should be recorded that the decision of The Geological Society to discontinue direct support to other societies was a matter of fiscal necessity.

CLAUDE ALBRITTON
*Treasurer*

RECEIPTS

| | | | |
|---|---|---|---|
| I. Balance brought forward from August 1, 1959 | | | $ 7,253.87 |
| II. Membership dues received: | | | |
| A. Dues from members receiving the *Journal of Paleontology* through the Paleontological Society: | | | |
| 1960 dues: 689 at $10.00 | | $6,890.00 | |
| 1961 dues: 6 at $10.00 | $ 60.00 | | |
| 1 at 8.00 | 8.00 | | |
| | | 68.00 | |
| 1959 dues: 21 at $10.00 | | 210.00 | |
| 1958 dues: 1 at $10.00 | $ 10.00 | | |
| 1 at $2.00 | 2.00 | | |
| | | 12.00 | |

| | | | |
|---|---|---|---|
| Total dues from members receiving *Journal* through Paleontological Society | | $ 7,180.00 | |
| B. Dues from members not receiving *Journal of Paleontology* through the Paleontological Society: | | | |
| 1960 dues: 105 at $2.00 | $ 210.00 | | |
| 1959 dues: 6 at 2.00 | 12.00 | | |
| Total dues from members not receiving *Journal* through Paleontological Society | | 222.00 | |
| Total, membership dues received | $7,402.00 | | |
| less bank service charge on Unesco coupons (3 at 50¢, 1 at 35¢) | −1.85 | | |
| Total membership dues accrued | | | 7,400.15 |
| III. Contributions in support of the *Journal of Paleontology*, received from the Penrose Bequest of the Geological Society of America: | | | |
| Special allocations for long manuscripts | | | |
| September 1959 issue | $1,377.00 | | |
| January 1960 issue | 597.00 | | |
| | | $ 1,974.00 | |
| September 1959 issue | $4,493.60 | | |
| January 1960 issue | 506.40 | | |
| | | 5,000.00 | |
| Total, contributions in support of the *Journal of Paleontology* received from the Penrose Bequest of the Geological Society of America | | | 6,974.00 |
| IV. Special contributions received in support of the *Journal of Paleontology:* | | | |
| The University of Nebraska, in behalf of paper of J. A. Fagerstrom | $ 500.00 | | |
| Christina Lochman Balk for extra plates | 50.00 | | |
| Total, special contributions received in support of the *Journal of Paleontology* | | 550.00 | |
| V. Apportioned income received from subscriptions and sales, *Journal of Paleontology*: | | | |
| 1959 remittance from Society of Economic Paleontologists and Mineralogists | | 4,086.62 | |
| VI. Income received from sale of 37 specimens of invertebrate fossils from the Silurian of Czechoslovakia to the Smithsonian Institution | | 10.00 | |
| VII. Contributions to the permanent publication fund | | 155.00 | |
| TOTAL RECEIPTS | | | $26,429.04 |

DISBURSEMENTS

(Check Numbers given in parentheses)

| | | | |
|---|---|---|---|
| I. Publication expense, *Journal of Paleontology:* | | | |
| September 1959 issue | | | |
| Plates and authors' reprints (403) | $1,349.48 | | |
| Printing (409) | 4,713.99 | | |
| | | $6,063.47 | |
| January 1960 issue | | | |
| Plates and authors' reprints (418) | $1,342.04 | | |
| Printing (422) | 4,237.56 | | |
| | | 5,579.50 | |
| May 1960 issue | | | |
| Plates and authors' reprints (424) | | 892.48 | |
| Half cost, annual index for 1959 (421) | | 108.26 | |
| Total, disbursements for publication expense of *Journal of Paleontology* | | | $12,643.71 |
| II. Publication expense, other than for publication of *Journal of Paleontology:* | | | |
| Correspondents of the Paleontological Society | | | |
| 7 members at $7.70 per member (423) | | | 53.90 |
| III. Special supporting contributions | | | |
| Zoological Society of London (414) | $ 50.00 | | |
| American Geological Institute (415) | 100.00 | | |
| Dues to International Paleontological Union (416) | 3.00 | | |
| Total, special supporting contributions | | | 153.00 |

| | | | |
|---|---|---|---|
| IV. Expenses of Offices of the Society | | | |
| A. Secretary's Office | | | |
| Addressing envelopes for ballots (404) | $ 28.50 | | |
| Printing (407) | 15.50 | | |
| Printing (420) | 32.25 | | |
| Printing (426) | 32.06 | | |
| Postage on ballots (405) | 10.00 | | |
| Printing and postage for PS luncheon announcement (406) | 30.00 | | |
| (412) | 4.25 | | |
| (419) | 1.00 | | |
| Travel subsidy, 1959 meetings (411) | 77.22 | | |
| | | $ 230.78 | |
| B. Editor's Office | | | |
| Secretarial expense, postage, etc. (417) | | 200.00 | |
| C. Treasurer's Office | | | |
| Secretarial expense (408) | $ 106.50 | | |
| Secretarial expense (428) | 61.50 | | |
| Postage (410) | 38.09 | | |
| Security Bond (413) | 5.00 | | |
| Printing (425) | 35.69 | | |
| Printing (427) | 40.10 | | |
| | | 286.88 | |
| Total, disbursements for expenses of Offices of Society | | | 717.66 |
| TOTAL, DISBURSEMENTS FOR FISCAL PERIOD ENDING JULY 31, 1960 | | | $13,568.27 |
| Cash-on-hand, July 31, 1960, in Hillcrest State Bank, University Park, Dallas, Texas | | | |
| Checking Account | $12,705.77 | | |
| Savings Account | 155.00 | | |
| | | | 12,860.77 |
| Total, disbursements for fiscal period August 1, 1959, through July 31, 1960, plus cash-on hand, July 31, 1960 | | | $26,429.04 |

## REPORT OF THE EDITOR

The Paleontological Society in the January, May, and September numbers of the *Journal of Paleontology* for 1960 published 30 articles on invertebrate paleontology, 6 on micropaleontology, 12 on vertebrate paleontology, and 4 on paleobotany, in addition to nomenclatural notes, notices, reviews, and Society proceedings and records. The total of 682 pages represents an increase of 12% in number of pages compared with 610 pages for 1959; the total of 80 plates is the same as for 1959.

In the interest of economy, 300 mesh halftone offset reproduction was used for all plates. In carrying out the ruling of the Council, no article in the May or September number was accepted with more than 5 plates unless subsidized for the additional plates. In the September number, the article

TABLE *1.* TOPICAL ANALYSES OF CONTENTS OF THE PALEONTOLOGICAL SOCIETY'S NUMBERS OF THE *Journal of Paleontology*

| Year | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 |
|---|---|---|---|---|---|---|
| Volume | 29 | 30 | 31 | 32 | 33 | 34 |
| *Pages of:* | | | | | | |
| Invertebrate Paleontology | 429 | 418 | 537 | 452 | 402 | 339 |
| Micropaleontology | 49 | 150 | 51 | 193 | 90 | 109 |
| Vertebrate Paleontology | 101 | 207 | 53 | 74 | 52 | 141 |
| Paleobotany | 8 | 19 | 8 | 11 | 38 | 36 |
| Notices, Records, etc. | 5 | 18 | 34 | 18 | 28 | 57 |
| Total Pages | 592 | 812 | 683 | 748 | 610 | 682 |
| Plates | 73 | 92 | 72 | 102 | 80 | 80 |

ROBERT V. KESLING

by Lochman and Hu had the cost of one plate borne by the senior author, and the article by Murphy and Rodda had the cost of two plates borne by the National Science Foundation.

As of October 15, 1960, the editor has on hand 52 manuscripts totaling 1017 manuscript pages and 68 plates. This compares with a backlog of 43 manuscripts totaling 1125 manuscript pages and 59 plates on October 12, 1959.

25 October 1960

TO THE COUNCIL OF THE PALEONTOLOGICAL SOCIETY

We, the undersigned, have examined the the ballots returned to the Secretary's office by October 15th in the Annual Vote of the Paleontological Society and find the following results:

1. Total number of ballots returned..... 400
2. Ballots invalidated by (a) absence of name on mailing envelope—76, or (b) name on inner envelope—8
3. On the 316 valid ballots the vote was as follows:

| | *For* | *Against* | *Blank* |
|---|---|---|---|
| (a) President, Norman D. Newell | 313 | 1 | 2 |
| (b) Vice President, Siemon W. Muller | 316 | 0 | 0 |
| (c) Editor Erwin C. Stumm. | 313 | 1 | 2 |
| (d) Treasurer, C. C. Albritton, Jr..... | 315 | 0 | 1 |
| (e) Secretary, H. B. Whittington | 315 | 0 | 1 |

On Proposed Changes in the Constitution and By-Laws of the Paleontological Society the vote was as follows: Total vote 306:

| *For* | *Against* |
|---|---|
| 298 | 8 |

Respectfully submitted,
ZEDDIE P. BOWEN
ALLEN S. HUNT
FREDERICK C. SHAW

REPORT OF NATIONAL RESEARCH COUNCIL REPRESENTATIVES

This year as in the past several years, all Divisions of the National Research Council met together. Most of the time was devoted to three panel discussions—Natural Resources, Grants and Fellowships, and Transportation. From the first and third panels, one gathered that although much thought is being given to major problems, no clear cut solutions are evident. The second panel discussion left the impression that government granting agencies are increasingly sympathetic toward large grants to institutions so that permanent buildings and expensive equipment may be acquired. Some attention was directed to problems created by NSF Fellowship grants which cause shortages of desirable graduate students available as teaching assistants. Discussion centered on various solutions such as limiting NSF Fellowships to the first or last years of graduate school.

In the Division of Earth Sciences, Dr. Adrian F. Richards has temporarily replaced Dr. William Thurston as executive secretary; he has since been replaced by Dr. Linn Hoover. The AMSOC committee ("Mohole Project") reported that the drilling sites have been moved to an area near Guadalupe Island, off Baja California. Three holes will be drilled, the first will be started next year, as funds are now available. The first hole will be jetted, the second will be drilled through soft material for a few hundred feet and the third hole will penetrate as far as time, money and operating conditions permit. Most discussion involved technical aspects. Plans have been made to collect some core samples.

The committee on the National Atlas of the U. S. reported progress on the looseleaf atlas which will incorporate standard sized maps from various government agencies. Thus far only geographic and meteorologic maps are prepared.

The oceanographic committee has published chapters 2, 3, 5–10, 12 of the Report on Oceanography and announced a symposium on ocean wave spectra to be held in 1961.

The most important item of interest to many paleontologists is the possibility that a study committee may be formed to investigate revitalization of museum collections. Programs might be set up in various institutions for the modernizing of their biologic and oceanographic collections, in particular those that have been neglected, un-

studied or poorly referenced. Some support has been indirectly given by the National Science Foundation for marine biological collections made many years ago and now made important by recent interest in oceanography.

Some discussion was given to the feasibility of extending this coverage to include paleontological and other Earth Science materials, should such a program be organized. Among other ideas resulting from this discussion was the possibility of institutional administrators taking this opportunity of reducing and consolidating collections to cut cost of storage and maintenance. The program could be a very important device for housing and caring for collections too long ignored because of prohibitive costs within individual organizations.

In the Division of Biology and Agriculture, an Ad Hoc on Marine Biology has been responsible for greater consideration being given that field by the NRC Committee on Oceanography. Much divisional activity continues to be devoted to problems of Education. Attention is directed to the excellent series of movies prepared by the A.I.B.S. Though these are designed for high school level, several may be useful in college teaching of Paleontology.

The 16th International Congress of Zoology will be held in Washington, D. C. August 21–27, 1963. Any ideas submitted for symposia topics or requests for local field trips will be forwarded to the organizing group. Washington is hot in August but the Congress hotels are air conditioned. Paleontologists were much in evidence at the 15th International Congress and it is hoped that the field will be strongly represented at this Congress.

Respectfully submitted,
ROGER L. BATTEN, *Division of Earth Sciences*
ELLIS L. YOCHELSON, *Division of Biology and Agriculture*

### JOINT COMMITTEE ON INVERTEBRATE PALEONTOLOGY

The task of pushing ahead the completion of the *Treatise on Invertebrate Paleontology* is being continued with unabated effort, which now is helped by a grant from the National Science Foundation that provides for research assistance to *Treatise* contributors where specially needed and also furnishes much needed aid for the Editor's office. Now, with support of this grant, we may expect confidently to complete our task within the next four years. Delay in publication of various units of the *Treatise* is caused mainly by changes in objective of the work. Instead of a condensed, up-to-date summary of invertebrate paleontology, comprehensive coverage of the subject in as authoritative a manner as possible is the aim. This requires time and much effort.

The first volume on Mollusca (Part I) was published in August, 1960. This contains an excellent general discussion of the phylum which is followed by sections on the morphology and systematic descriptions of Scaphopoda, Amphineura, and Monoplacophora. Then follows a general description of Gastropoda which fully describes features of both soft and hard parts and which is followed by an extended description of taxa belonging to the Archaeogastropoda and some additional groups which are important in Paleozoic strata. Lamentably, Dr. J. Brookes Knight, who contributed very largely to this volume of the *Treatise*, did not live to see it in finished form. This is unhappy because Knight considered his contribution to the *Treatise* one of the most important of his scientific career and he was unable to see it in finished form. However, Dr. Knight did see proofs of the text and illustrations.

The next-to-be-published unit of the *Treatise* is concerned with Ostracoda, which will be comparable in size to Mollusca I and Arthropoda I, recently published. All of the text for this unit has been set in type and most of the proofs for illustrations have been provided. This volume should be ready for distribution early in 1961.

The volume next for publication is Part W which contains the conodonts, worms, and Problematica. Desirably, this unit should be one of the last to appear, but because the materials for it have been submitted and because Dr. W. H. Hass, author of the section on conodonts, died prematurely, publication should not be delayed.

Units which are expected next to be made ready are those concerned with the Foraminifera and primitive Echinodermata. Most of the needed text and illustrations for these volumes has been prepared.

In July the Editor had a conference with British authors of divisions concerned with Brachiopoda at a meeting held in London. A good deal of work on this group has been finished and plans for pushing ahead completion of the remainder of this task have been made.

Joint Committee on Invertebrate Paleontology
R. C. MOORE, *Chairman*

## REPORT OF THE REPRESENTATIVE OF THE PALEONTOLOGICAL SOCIETY ON THE COMMITTEE AND COUNCIL FOR SECTION E-GEOLOGY AND GEOGRAPHY OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The American Association for the Advancement of Science, Section E (Geology and Geography) met jointly with the Geological Society of America at Chicago, Illinois, December 27–30, 1959. Symposia were held concerning Quantitative Terrain Studies, Great Lakes Basin and Origin and Development of Limestone Caverns. Byron N. Cooper, retiring chairman of Section E, gave his vice-presidential address on "The Role of Subsidence in the Origin and Evolution of the Appalachian Mountains." Howard A. Meyerhoff assumed vice-presidential duties for 1960 and Frank C. Whitmore, Jr. continues his duties as secretary. The new Section E Officers are William C. Krumbein, Vice President and Chairman and Frank C. Foley, Committeeman-at-Large.

Membership in the AAAS covers all fields of science. Its program, including the official publication *Science*, is quite diversified. Since topics of direct paleontologic interest have not been included in sessions during the past year or two, I would urge that society members offer suggestions to Section E officers for a future symposium dealing with current developments in our science. Topics should be broad and have appeal to scientists form the allied fields.

R. C. GUTSCHICK

## NOMINATIONS FOR OFFICERS IN THE PALEONTOLOGICAL SOCIETY FOR 1961–1962

In accordance with provisions of Chapter III, Section 1 and 2 of the By-Laws, the Council of the Paleontological Society announces the following nominations for the offices in the Society for 1961–1962:

For *President*—JOHN W. WELLS, Ithaca, N. Y.
For *Vice President*—RALPH W. IMLAY, Washington, D. C.
For *Secretary*—H. B. WHITTINGTON, Cambridge, Mass.
For *Treasurer*—CLAUDE C. ALBRITTON, JR., Dallas, Texas
For *Editor*—ROBERT V. KESLING, Ann Arbor, Michigan.

In accordance with Chapter III, Section 2 of the By-Laws it is provided that "Any twenty members may forward to the Secretary other nominations for any or all offices. All such nominations reaching the secretary at least sixty days before the Annual Meeting shall be printed, together with the names of the nominators, as special tickets."

## PALEONTOLOGIA ENIGMATICA CASTER*

This is the third Annual Luncheon of the Paleontological Society. So far, no fixed program for this pleasant event has developed. Perchance I am to-day establishing a precedent in offering you my valedictory remarks on this occasion.

These remarks take the fom of a brief, but hearty welcome to all: members of the Society; guests for at home and abroad; ladies and gentlemen.

Undoubtedly, this is where I ought to stop. Both intuition and external advice counsel this. However, perversely, I shall tender you the distillate of a prolix "presidential address" as a welcoming précis:

Welcome: fellow geologists and stratigraphers.

Welcome: brother oryctologists,—all who "dig things up"; useful things; mappable things; curiosities. Number lends us courage

* Remarks by Kenneth E. Caster, retiring President of the Paleontological Society, Denver, Colorado, November 1, 1960.

in the face of imminent technological unemployment. The traditional stock in trade of "dug up" things is fast losing its stratigraphic market. Our chronologic wares grow obsolescent. Chemists and physicists, and all other chronologic technicians who supplant us: we salute you! "The king is dead; long live the king,"—or am I somewhat previous? (I, for one, am reconciled to our professional extinction; welcome it, in fact; for, in our passing, long over-due, the field of, "paleontology," which we have dominated for far too long, will then be open for the more promising, and contemporary, thought and action of paleobiology. Ours has been from some time now an anachronistic *art.*)

Salutations to the lawyers and pettifoggers among us; to the nomenclatorialists and taxonomists; to all, and I have long been one of you, who make obiesance to priority and irrelevant codes (ours seems to have died aborning); to the mathematicians;—yes, to the actuarians, if such be here; welcome, I say, to all of you who are more concerned with legal form, names and numbers than with Nature herself. (Mind you, documentation is but an art; discussion and synthesis: science,—albeit they are dangerous!)

Smilax and waffle-irons (to paraphrase Dwight Fisk) for all the makers of learned lists (which garnish the reports of others); for all the myriad automatons of the "Identify and Report" production-line.

Welcome, I repeat, all you paleontologic colleagues who spend your days on other work. Your name is legion in the halls of Academe, industry and bureaucracy. Welcome, and *bem vindo*, all you ambivalent ones; you workers on committees, talc, kaolin and coal, fluorspar, iron and structure; you sedimentationists, mappers, editors, bibliographers and administrators,—a melancholy welcome here!

(Note: no censure is intended for a job well done; only for that which, by so doing, you neglect: namely, the career-that-might-have-been; for which you presumably trained; and which you now let rust. Some grow resigned to this abandoned life in sin; the apathetic ones, strained unduly by the double yoke, crack in heart and mind; whilst others,—and sadder is their fate, the poorer ours, simply "take it with them": their life-store of data undigested, collections chaos, notes scrambled, and manuscripts unwritten. These, I vow, are ill-spent lives!)

(But congratulations too; few professionals have such multi-stringed bows as we. Does this disprove the adage that "Jack-of-all-trades masters none"?)

Hail, too, those presumably absent colleagues who contentedly plough our field,—although untrained for its requirements. Welcome to the masquerade, I say! Their biologic mask ill-conceals their geologic face! (These imperceptive associates are more charitably considered as casualties of the system than wilful mimes; fortunately, editors tend to keep their travesty from print.)

A special fraternal clasp for those low men on academic totem-poles: the sedimentationists, stratigraphers, instructors in mineralogy, and lady petrographers*, tyros all, who find themselves inculcating, as best they can, the art of oryctology, if not the science of ancient *living* creatures. Theirs is an "A" for effort. And to their students, if there be any here today,—a very special, heart-felt, greeting!

Highly personal greetings to all those who father taxa wholesale, sparing us the boredom of more than minimal substantiating prose or pictures. When fossils fail, there will always be your works to revise, your names to honor, and your taxa to elaborate. And, let us not forget those artists among us who retouch: our greetings too. Imperfect Nature needs your heavy hand; mutation has not wrought enough!

Greetings: illustrious custodians of collections, directors of museums: zealous factotums, your hoards of types and books are certainly more precious than the Ft. Knox-trove, but their appeal far less universal! Let down your guard: not all of us

* An asterisk for one of those "lady petrographers," last in the pedagogic "pecking-order" at her school: apologies for my tantrum. But you must admit it was disconcerting to discover those type specimens, which I have traveled half the world around to study, reposing in your laboratory teaching set, *sans* labels, scratched and soiled! Did you ever make that day's excursion to your fossil sites for replenishment of your teaching stock? Or have you fallen back completely on the picture-books?

are thieves; the mails are safe; our laboratories have the means for study which the most reluctant of you fail to provide. Types exist for study; books to be read. Do ease your regulations; lend us both!

Welcome: those who worship types; also the typeless anarchists among us.

Welcome: those whose specimens are species; and those who function as though our science ended with James Hall, Barrande and Cuvier.

Welcome, you friends, for whom the ancient world is flat, who seem to spend your days swapping fossil-studded pancakes, as though migration were *instanter*, like Creation; homotaxis and facies quite unknown!

"Nationalists" among us, too, be welcome here. Let any nuance of time, place or layer replace outmoded *form*,—if jingo-pride and fatherhood are better served thereby! When every realm and every age has its own indigenous taxonomy, then, no doubt, will another Linné come to lead us out from Babel. Meanwhile, after us the deluge!

Salve and salud to the paleoecologists among us! These worthies salvage the best of our two worlds. They manage to transcend the insulating void between the physical and biologic. (At least, that is their aim. Unless the bridge exists, the paleocological alchemy does not transpire.)

Muted drums for the "synecdochists" among us: for all those colleagues whose trees are forests, whose parts are whole. Theirs is the "medals of creation" school, for whom the index is the book. No need to labor here the point that fossils are neither "things" nor vestiges, *per se*, to be viewed, in Huxley's terms, "as a savage looks at ships," but part of an organic whole: the potential basis for restoring the continuum of a living past. Herein our science; therein, at best, but art.

("Fossils are not organisms"; no; but that is their challenge to the well-trained, resourceful mind. The closer to their fulsome restoration we can come, in form, in function and association, the nearer do Paleobiologists come to goal.)

*Greetings*, too, for the jugglers of words; for the quoters *in extensio* and *ad verbatim;* in brief, for all those obsessed with the winnowing of the written chaff: fellow practitioners of the literary cult of decadence; for all who admire more what has been "stated," than what *is*. Our literature is vast.

A golden welcome, appropriately, to our colleagues and friends in economic paleontology! Mutual respect and cooperation have long marked our association. In serving self, you serve us all. Moreover, should current trends continue, you may yet bring us to man's stature as a science! Better than the common run of us, you keep art and science separate, Bitter though the pill may be to some, our science has greater stature in many of your laboratories than in most schools and bureaus. You are the Phoenix, —happily emerging before the holocaust!

An old, familiar, and, I hope, unstrained, welcome here, all you from whom we are of late divorced, dear vertebrate- and vegetable-loving friends. Too few of you are here today; too seldom do we meet. Blame lies with us, no doubt. Obviously you prosper in the more animated associations you now enjoy. We envy each of you, vertebrate paleontologists and paleobotanists, the sparks you strike; the common cords that bind you close; the neontologic alignment which abets your work, yet makes no exigent demands. What luck to be so "useless" to your Recent friends! (We sometimes feel you bear a grudge; stay too far away. Perchance a little of our common clay would make good soil for your biology; Your fossils, like our own, are stone; revealed by geologic lore. Achilles had his foible; could be that geology is yours!)

Naturally, the rhetoric of our encomium, above, precludes exceptions. Ne'er the less, spore-loving friends, and highly "useful" too, palynology is not here forgot; nor any others of a "micro-cline." Your presence here is genuinely appreciated.

Most cordial welcome here, indeed, to those who, despite the vicissitudes of ignorance, pressures, poverty,—and scorn, manage to keep flickering the tenuous flame of invertebrate paleontology. (These are the heroes of this time and place.)

And, finally, heartiest welcome to you all: fellow practitioners of the catholic and heterogeneous, artful, *enigmatic* "science" of paleontology. The cohesion of such hours as these may yet stem the debilitating, centripetal disruption so long manifest in our works.

PROPOSED NEW MEMBERS

In accordance with Article 3, Chapter 1, of the By-laws of the Paleontological Society, the names of new members approved by the council are as follows:

ALLISON, EDWIN CHESTER, Department of Geology, San Diego State College, San Diego, California: J. Wyatt Durham, Joseph H. Pack, Jr.

AMOS, ARTURO JORGE, Dept. de Geologia, Fac. Cicucias Exactasy Nat. Perú, 222, Buenos Aires: G. Arthur Cooper, J. Thomas Dutro, Jr.

BEERBOWER, JAMES RICHARD, Dept. of Geology, Lafayette College, Easton, Pa.: T. W. Wells, W. Stores Cole.

BEUS, STANLEY SPENCER, 10771½ Strathmore Drive, Los Angeles 24, California: W. P. Popenoe, C. A. Nelson.

BIEBER, CHARLES LEONARD, 311 Greenwood Avenue, Greencastle, Indiana: R. C. Gutschick, H. B. Whittington.

BOEHME, RICHARD W., 588 Starin Avenue, Buffalo 23, New York: Edward A. Buehler, Irving H. Tesmer.

BOURN, OSCAR BENJAMIN, 5518 Alvarado Road, Amarillo, Texas: William McBee, Jr., Paul W. Nygreen.

BOWEN, ZEDDIE PAUL, Museum of Comp. Zoology, Harvard University, Cambridge, Mass.: H. B. Whittington, B. Kummel.

BRADY, RAYMOND ADAM, 1804 Louisa St., New Orleans, La.: E. Vokes, H. C. Skinner.

BUTTNER, NATALIA PRAJMOVSKY, 417 Rockaway Ave., Valley Stream, L. I., N. Y.: B. Kummel, H. B. Whittington.

CALDWELL, WILLIAM GLEN ELLIOT, Department of Geology, The University of Saskatchewan, Saskatoon, Saskatchewan, Canada: F. D. Holland, Jr., Chas. G. Winder.

CAREY, RICHARD S., 190 Ellison Ave., Roosevelt, L. I., N. Y.: B. Kummel, H. B. Whittington.

COLQUHOUN, DONALD JOHN, Dept. of Geology Univ. of South Carolina, Columbia, S. C.: Harold, W. Scott, Harold R. Wanless.

DAHLBERG, ERIC CHARLES, South Boulevard, Nyack, New York: Robert Ramsdell, Karl M. Waage.

DARBY, DAVID GRANT, Museum of Paleontology, Univ. of Michigan, Ann Arbor, Mich.: G. M. Ehlers, Erwin C. Stumm.

DAVIDSON, EDWARD SYLVESTER, 2001 Ridgeway, Arlington, Texas: Fredda Jean B. Lackman, G. Arthur Cooper.

DAWSON, JAMES MARTIN, 65 Hayward Avenue, St. Johns, Newfoundland: F. D. Holland, Jr., Richard D. Hughes.

DRISCOLL, EGBERT GOTZIAN, Museum of Paleontology, University of Michigan, Ann Arbor, Michigan: G. M. Ehlers, Robert V. Kesling.

EICHER, DON L., Department of Geology, University of Colorado, Boulder, Colo: John Chronic, Harold E. Koerner.

FARMER, GEORGE THOMAS, JR., 666 N. Crescent Avenue, Cincinnati 29, Ohio: K. E. Caster, R. G. Osgood, Jr.

FELDMAN, ROBERT HOWARD, 1402 2nd Avenue, N., Grand Forks, North Dakota: F. D. Holland, Jr., Wilson M. Laird.

FRANKLET, GEORGE ALBERT, Box 705, College, Alaska: F. D. Holland, Stanislaw J. Poborski.

FRYE, CHARLES ISAAC, Geology Department, University of North Dakota, Grand Forks, N. D.: Mark Rich, F. D. Holland, Jr.

GARTNER, STEFAN, JR., 64 Evans Ave., E. Hartford Conn.: Larry Frankel, Karl M. Waage.

GEN, GEORGE FLEMING, Lovers Land and Schaefer Roads, R.D. 3, Norwalk, Ohio: L. De Mott, H. B. Whittington.

GREENE, BRYAN ANDRÉ, 18 Hayward Avenue, St. Johns, Newfoundland: F. D. Holland, Jr., Richard D. Hughes.

HANNEN, GERTRUDE M., Apt. 309, 1039 W. Hollywood St., Chicago 40, Ill.: John N. Pope, K. Caster.

HEASLIP, WILLIAM GRAHAM, Geology Department, Syracuse University, Syracuse 10, New York: Norman D. Newell, John Imbrie.

HECKEL, PHILIP HENRY, 181 Oak Lane, Rochester 10, New York: Anthony Reso, Karl M. Waage.

HICKERNELL, ROBERT LOWELL, JR., Richfield Oil Corp., P.O. Box 147, Bakersfield, California: Stanley Carlson, J. Wyatt Durham.

HIRSCHFELD, SUE ELLEN, 2601 NE 23rd Street, Ft. Lauderdale, Florida: Harold K. Brooks, Ronald Echols.

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